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A Study in Power Transmission.

A very interesting study of power conditions in the mines of the Witswatersrand appears in a recent number of the Proceedings of the Institution of Civil Engineers. It is of particular value because the investigation of actual power and costs at the mines was an exceptionally full and thorough one and because, in addition to estimates on transmitted electrical power, the mooted question of the transmission of gas to gas engines from a source convenient to coal mines was carefully considered. This last proposition has rarely received much attention, and it would be difficult to recall an instance in which it has heretofore been included in a comparison with local steam power and power electrically transmitted. The situation on the Witswatersrand is peculiarly interesting from its relation to the Victoria Falls power scheme, involving a transmission of some 700 miles. Mine power in general is costly on account of the necessary situation of the apparatus and the very heterogeneous nature of the work to be done. Such tasks as driving hoists and air compressors are not favorable to electrical operation, in point of efficiency, and all the work of a mine is accomplished under conditions which are rather severe. In the study of the power situation in this case 17 producing mines were investigated in detail, the power used being carefully measured, whenever possible, under all working conditions, so as to obtain as accurate an estimate as possible of the total yearly requirements.

The total figure for power is a big one, for the mines averaged nearly 10,000,000 i.h.p. hours yearly, the total for the 17 mines being about 160,000,000, which, since it is practically all 24-hour power, amounts to a constant load of over 18,000 h.p. The total load, in fact, is fairly uniform, which must be taken into account as a favorable item in any reckoning with central power supply. In the investigation of the electrical power proposition the actual capacity of the motors needed was determined, so that operating costs could be fairly estimated. In this way the actual economies of the situation come to light with a distinctness very unusual in estimates of this sort. It is no small task to do the work thus thoroughly, but the results are correspondingly valuable. In making the estimates of the present cost of power, interest and depreciation were not regularly taken into account, since the purchase of power would not enable the mines to get the original investment cleared away. As in most cases of purchase of electrical power by an existing plant, the old plant is not a practical asset to any material figure, and its disuse merely clears away the upkeep. As might have been expected, the costs of steam power varied greatly from mine to mine, nor did the cost bear any definite relation to the total yearly output. The lowest yearly figure reached was about $118 per i.h.p., or 1.335 cents per i.h.p. hour. The highest was about $260, or 2.47 cents per i.h.p. hour, the average yearly cost being not far from $135. This appears at first sight a pretty stiff figure, but under the load conditions it is not so bad, and, good or bad, there is no reason to doubt its reliability for the purpose considered.

On its face such a figure would indicate that transmitted power would find here a ready field. But there are considerable charges to be considered before one gets to a possible price for power. It is much to be regretted that the investigators did not go in detail into the costs by the gas project. They content themselves by saying: "It was soon evident that the mine costs of running gas engines were so high that only an impossibly low figure could be paid for the gas, and the calculations were therefore abandoned after being carried out in respect of four mines only." This statement of itself is certainly quite enough to discourage one in undertaking the transmission of gas, but the cost of such transmission is very intimately related to the conditions of operation at the receiving end, so that there might well be certain cases in which it would be economical. In looking into the matter of electrical supply, the three-phase system was assumed for the distribution, with possible modifications in case of some variable speed motors. The costs would not in any event vary widely, nor would the efficiencies concerned, so that the results may probably be taken as representative. The costs of electrical equipment and operation were fully taken into account, together with 5 per cent. interest charge and also amortization of the costs over the probable life of the mine. This last item is a somewhat necessary one in figuring mining matters, and, in fact, one of the producing mines in Johannesburg was left out of the whole examination on account of probable exhaustion within a few years. From the data thus computed it was possible to compute for each one of the 17 mines the maximum figure which it could pay per electrical horse power year and still break even in the matter of cost with the present steam operation. Obviously, some figure lower than the maximum would have to be met by an electrical supply company to induce interest in electric power.

The lowest point touched by this maximum price is about $66.50 per electrical horse power year, while the highest figures are more than double this, the average, so far as an average can fairly be reached in so varied conditions, being somewhere about $90. Commenting on these figures, the investigators doubt whether an electric power company could make reasonable profits after underselling the maxima to a reasonable degree. Judging from American practice, the chance for electricity would look altogether excellent, unless a very abnormally costly transmission were undertaken. There are plenty of American companies that would tumble over themselves for the chance of getting a reasonably steady 24-hour load at $50 per electrical horse power year, let alone $60 or $70, which figures would still be well over the average. There is, however, one element in this particular case not easy to value. That is the prospect for continuing business, which depends on the character and prospects of the mines. The data on probable life of the mines are not disclosed in the paper, and they might, of course, be of such a nature as to make the electrical investment non-permanent and hence necessary to be protected by an amortization charge of uncertain amount. Yet it seems hardly possible that the future prospects of this part of South Africa are bad. On the contrary, its possibilities are great, and one can hardly imagine it playing the role of a "busted" mining camp. Even if capital be overcautious in South Africa, it would seem good policy for the mines to go into a mutual power pool for the large saving that can certainly be made. Although of various ownership and interest, it would be indeed strange if all would not join in a campaign of economy. Certainly if the Witswatersrand were in the domain of Uncle Sam a power scheme would have been syndicated long before this, and the last steam engine would have ceased its thumping.

The Panama Canal.

A few weeks ago Mr. John F. Stevens, formerly chief engineer of the Panama Canal, delivered an address at New Haven which was reported in many newspapers to be a rather severe criticism of certain features of that undertaking. The reports seemed entirely at variance with opinions privately expressed by Mr. Stevens and those acquainted with the good work he did on the Isthmus and his high opinion of what is now being done there were disturbed at the general acceptance of the reports as authentic. A full copy of his address, just received by this journal, shows there is nothing in it from one end to the other to justify the reports made in the newspapers regarding his criticisms. When he went to the Isthmus he had a great work cut out for him to do, and that he did it very well indeed is the testimony of those who are best able to judge of its value. It was his main task to form an organization for carrying on construction work, and that organization, with minor modifications which necessarily arise in every great undertaking, is still in use. The address is interesting on account of the clearness with which it outlines the difficulties of inaugurating that work. When he took charge of operations, there was, it is true, an organization, but he did not find any co-operation between its parts nor any systematic plans for carrying on construction along lines promising success. Moreover the white employees were in a state of alarm concerning yellow fever, a number of cases of which were then prevailing. For a good many months it was necessary to perfect plans of many sorts, for sanitation, for the reconstruction of the Panama Railroad and for the actual work of excavation along the canal. At this time, it must be remembered, the decision concerning the type of canal had not been finally reached. It was then that complaints were most common because dirt was not flying, and the country should be thankful that Mr. Stevens resisted the clamor for more digging at that time and went ahead with the necessary preliminary work. He was unwarrantably criticized then, just as he has been unwarrantably criticized recently for things he did not say.

The rejuvenation of the Panama Railroad, he states, was one of the hardest problems that had to be met in getting ready to push the canal construction. It had but a single track, practically no sidings or station buildings, a worn-out telegraph line, no terminals worthy of the name, and motive power and rolling stock that were obsolete twenty years before. While a fair amount of new equipment had been ordered, little or nothing had been done to place the road in proper shape to handle the heavy business suddenly thrown upon it. Traffic, both that pertaining to the canal and commercial, local and through, was nearly at a standstill; thousands of tons of through freight were piled in cars, warehouses and on docks, and some of these shipments had lain from three months to a year and a half in the hands of the railroad company, and in many cases even the shipping papers and records of this freight had been lost. All these congested conditions had to be cleaned up, the road rebuilt, reorganized in its operating features and personal, taking care at the same time of a constantly increasing traffic. All this was accomplished so that the Panama Railroad one year ago was placed in a condition fit to compare favorably with the average of our best American roads.

Another problem to be solved was hiring and caring for the great number of skilled and unskilled laborers, the clerical and supervising forces requisite to carry on the work. Nothing in Mr. Stevens' remarks concerning this work can be considered a criticism of the government's action during his charge of the work or subsequently. He points out that various laws which Congress has passed make the cost of a day's labor, measuring that labor by the efficiency of the workmen in the United States, unusually high, and he states that he favored the introduction of Chinese whom he knows to be superior from every point to the laborers on the Isthmus, but was overruled for reasons never explained to him. A statement of fact like this is certainly not a carping criticism, but is an assertion which a good many people, who have wondered that Chinese were not employed on the work, will be glad to see. The address is very frank concerning the strain that the heads of the enterprise were under during the time when this force of men was being collected, and their housing and food supplies were being planned. The work was surely a very arduous one, and there can be no reason for Mr. Stevens denying that the strain of carrying it along was sometimes a heavy one. But it finally resulted in a real, effective organization, working steadily and surely toward a definite end, which the men eventually recognized and appreciated, and in that recognition those who were in charge found the main reward for their work. It is somthing to be proud of to put heart into a dispirited army of 25,000 men.

So far as the general plans for the canal are concerned, Mr. Stevens makes no criticism. He went to the Isthmus rather in favor of a sea-level plan, but he abandoned it after a personal study of the conditions and he gives his reasons for believing that the lock canal now being constructed is the best. It is interesting to learn that he recommended during his term of office the construction of locks at Miraflores and Pedro Miguel instead of at La Boca. The abandonment of the La Boca locks, it will be recalled, has only recently been approved. His statements concerning the cost and time of completion of the canal are interesting, but they cannot be considered in any sense criticisms of the government's course. So far as the length of time necessary to complete the canal is concerned, he points out that this depends upon many conditions, some of which may change all calculations. Allowing proper time for contingencies, however, he believes that seven years more will see the canal in operation. As to its cost, he states frankly that all estimates at the present time are guess-work. He is of the opinion that $200,000,000, in addition to the money already paid to the French company and to the Republic of Panama, should complete the work as planned originally, but on account of changes made in the locks, more money must be spent.

The much criticized portion of his address referring to the utility of the canal is merely an expression of individual opinion. With the Panama Canal completed, he estimates that it will take a war fleet moving as a unit at least 17 days to steam from Hampton Roads to San Francisco, and 17 days is a long time to wait when 13-in. shells are falling into a city. The idea that a navy can be thrown from one ocean to another, like a hot potato from hand to hand, does not appeal to his mind, and accordingly some of the statements made concerning the military value of the canal do not seem to him particularly well founded. He also states that he cannot see where the traffic is to come from which will make the canal a paying investment for a good many years. In his opinion it must handle a larger tonnage each year from the very opening than the Suez Canal did after 36 years of use in order to be self-sustaining at any rates of toll which will not serve as a bar to its use. Statements like these cannot be considered unfounded criticisms of a great undertaking or the utterances of a man who is disgruntled because he is no longer connected with the works to which he refers. The Engineering Record calls special atention to them because in many journals Mr. Stevens has been criticized as a grumbler, without any warrant whatever. His address is really a plea for the support of the government's work, based on an intimate knowledge of it that only a very few people possess.

Inviting Plans and Bids on General Specifications.

It is almost a universal system of procedure to invite bids for engineering work on specific plans and specifications, and it is unfortunate that the few exceptions to that rule generally relate to works of unprecedented dimensions and extraordinary character, precisely the cases where the conditions on which bids are requested should be more than ordinarily clear and well defined. It is not a matter of great moment should some of the conditions prescribed for works of ordinary magnitude fail of exact realization, but it is quite different with works of extraordinary magnitude. This feature of contracting for great engineering work has been given remarkable emphasis as have many others in connection with the Quebec Bridge failure. There is printed on another page of this issue of The Engineering Record, Appendix 18 of the Report of the Royal Commission on the Quebec Bridge failure setting forth the conditions under which bids were invited for that ill-fated structure, and which unfortunately led to the train of untoward circumstances finally producing the greatest mass of steel wreckage which the world has ever known. That portion of the Royal Commission's Report to which allusion is made indicates with great fullness the kind of procedure above all others which should not be followed in securing bids for construction.

The chief engineer of the company elaborated general specifications which in a way were sufficiently full for his purpose but which failed even to indicate what plan of bridge was to be adopted and how certain important parts of the processes of construction and erection should be conducted. There were other essential points in which he failed to set forth provisions for more or less important parts of the work. As a natural result there must have been in the minds of prospective bidders much uncertainty, some necessarily of a gambling character, without using that term offensively, and some of such a nature, at best, as to make it impossible for an experienced contractor to bid with reasonable closeness without hazarding perhaps a fatal loss in the final outcome. The uncertainty of plan alone involved in its train all kinds of still other serious uncertainties regarding kind and quality of material as well as processes of erection and a large class of other conditions which ought not to be grounds of speculation in the bids invited. These untoward conditions were greatly aggravated by the fact that the chief engineer of the company who drew up the specifications was not an experienced bridge engineer so that his compilation of specifications was not consistent in all parts nor efficiently adapted to secure his desired ends.

It will be remembered that both a stiffened suspension bridge and a cantilever structure were contemplated by the bidders and that when the contract was finally awarded it became obviously necessary to modify and amend the specifications on which tenders were based. Furthermore, this opening of the specifications for material changes led to a long train of characteristic evils, among which are found inadequate treatment of the general plan of structure, still more inadequate consideration of the design of certain main members of the trusses and a number of similar defects, all of which are usually and should always be matters of most deliberate study and treatment by the engineering organization responsible for the complete design of the structure. In the present case the contractor appears to have given a far greater detailed consideration to the various features of design than the most experienced and competent builders are usually expected to bestow upon this part of their work, and it appears, further, that no procedure was followed without the prior official approval of the consulting engineer who in this case was the responsible engineer. The circumstances under which the processes of design, manufacture and erection were set forth and executed were such as to preclude the deliberate attention which such parts of a great structural work should receive. It is no time to make studies in design either of general plans or of main members after manufacture has begun. All such questions should have been thoroughly studied prior to the beginning of shop operations. Provision also should have been made for all tests of full size members equally early in the history of the enterprise; indeed, if tests of full size steel compression members were to be made at all, they should have been made prior to the design of the truss members themselves.

It is true that a pound price contract for a steel structure gives opportunity for much elasticity of operations in the progress of construction, not possible in a lump sum contract, but that feature does not preclude some of the worst difficulties of the situation. The great questions on which the efficiency and safety of the contract operations depend remain open until it is too late to give them proper consideration, no matter how correct the intentions or the motives of the responsible engineer and the contractor may be. The greater and the more unprecedented a structural work is, the earlier, the more prolonged, the more deliberate, and the more thorough should be the study devoted to every unusual feature of the undertaking from its beginning to its completion, and anything which trenches upon the means of attaining those ends dangerously threatens the success and safety of the enterprise.

No one can read the melancholy story of the attempted building and collapse of this great and ill-fated structure without discerning the most pointed lessons regarding the proper conduct of every stage of progress in such an undertaking from the making of the specifications to the completion of erection. It is one of the most depressing features disclosed by the Royal Commission's investigation to observe that some of these lessons, at least, were too plain to have been so obviously violated.

Notes and Comments.

The Institution of Civil Engineers is about to erect a larger house with a more commodious auditorium on the corner of Great George and Princess Sts., Westminster, for the site of the present home is required for a Government building.

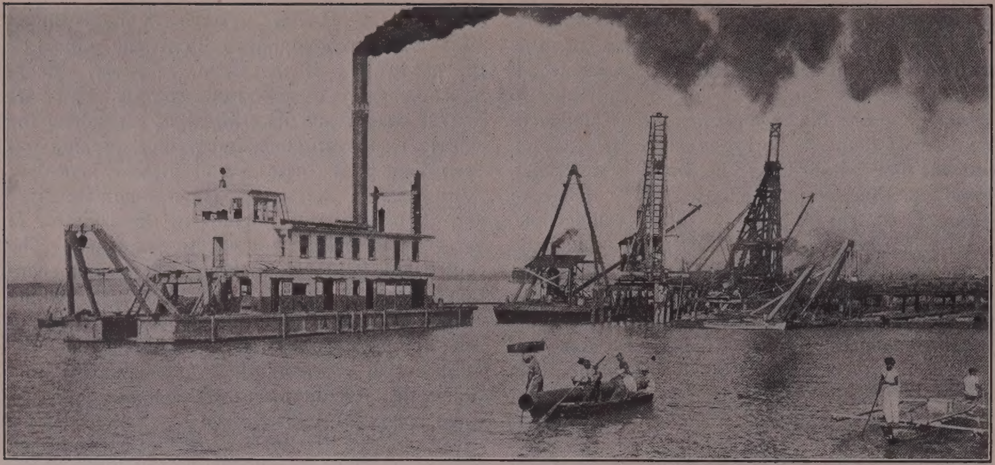
Taxation of Water Powers in Connecticut is regulated by Section 2,344 of the general statutes of 1902, which provides that "when water power, created or reserved in any manner by works wholly located in the same town in which it is applied and used, is used by its owner, the whole shall be assessed and set in the list as incident to the machinery which is operated by it and not separately as distinct property; and when such power, or any part thereof, is leased from its owner, it shall, to the extent to which it is so leased, be assessed and set in his list at its fair valuation, based upon its net rental." The Supreme Court of Errors of the State has recently been called upon in the case of the Hazard Powder Co. against the town of Enfield to interpret this statute in a rather unusual case deserving the attention of owners of idle power plants. Prior to 1904 the company operated two plants for making gunpowder, both run by water power developed at works lying wholly within the town. In 1904 the company discontinued work at one of its plants and permanently closed its mill there. In the following year it discontinued work at the second plant and shut it down as soon as the materials on hand had been worked up. The town claimed that, although these plants were permanently shut down, they should be assessed under the statute, while the company insisted that it was unjust to tax it for water power which it never intended to use. The court rules that an owner of water power, having it applied to its own mill, so that it is available for immediate use in connection with the mill, is using it within the meaning of the statute quoted, so that it should be assessed as incident to the machinery, though the mill and machinery stand idle and though it be the owner's intention that they shall remain permanently so.

Timber Preservation by open-tank methods of treatment is to be demonstrated practically by the U. S. Forest Service, which will erect plants for the purpose near the Black Hills National Forest in South Dakota, the Holy Cross National Forest in Colorado and the Henrys Lake National Forest in Idaho. These demonstration plants will be constructed on a fairly large scale in order to prove that this method of treatment is applicable to such commercial work as does not require the more elaborate method for which vacuum and impregnating cylinders are needed. The principle of the method is to immerse thoroughly seasoned wood in a hot bath of the preservative liquid, leave it there for a few hours, and then either plunge it into a cold bath of the preservative, or else run out the hot liquid from the treating tank and fill it up again with liquid of a lower temperature. Treatment of this sort enables lodgepole pine, Engelmann spruce and other relatively cheap woods to be used in place of more expensive species. The officials of the Forest Service believe that by encouraging this method of treating inexpensive timbers the timber resources of the country can be materially benefited. The process can be carried out on a small scale as well as on a commercial scale, and the Forest Service is ready to co-operate with all who wish to give it a trial. It is one more step toward the better utilization of our timber resources and accordingly deserves the support of engineers throughout the country.

A Water Meter problem is discussed in one of the newspapers of Rochester, N. Y., in such a clever manner that a brief mention of it is worth while, particularly as the deduction reached by the newspaper is wrong. It is acknowledged in this article that water should be measured and charged for according to the quantity consumed, but a mistake is made in saying that this policy can be carried too far. The mistake is a natural one, since it is based on a desire to keep the charge for water to the poorer people of the city down to the present minimum, which, it is asserted, is impracticable if a meter is required in houses where there is but one faucet. It is unquestionably true that such an opinion is widely held, but is is slowly disappearing with the growth of a better appreciation of just what part the meter legitimately plays in the general system of water-works administration. No gas company will furnish gas except through a meter, no matter how small may be the quantity used in any house. The meter is looked upon as a part of the plant, just as much as the retorts, holders and mains. It is not the property of the consumer, but of the gas company. Its cost is not charged against the consumer, but is a minute item in the whole cost of the entire gas works. This is the right view to hold of the water meter, although unfortunately a great many cities are still endeavoring to charge the meter directly to the consumer. When this later course is followed the cost of metering the small houses is quite high in proportion to the other plumbing, and arouses vigorous objection which would be absent were the meters paid for by the water department. This is important because experience has shown in many places that the waste of water in the poorer classes of houses is quite large. It is just as important to check waste in the house of a laborer as in the house of the most wealthy citizen. Until quite recently it was often asserted that the greatest proportion of waste took place on the premises of large consumers, and careful house to house inspection indicates that this may be true in some cities. But it is equally true that investigations have shown an enormous waste taking place in houses with but few fixtures and since the purpose of water meters is not only to determine the amount of the charge which should be made to each consumer but is also to prevent the waste of water which serves no useful purpose, it is desirable to have meters installed on all services, as a matter of sound business policy.

A Water Conservation Conference was held in New York on April 9, which was indicative of the interest now shown in such subjects in many parts of the country. It was a meeting of representatives of the State Water Supply Commissions of New York, Pennsylvania and New Jersey, the U. S. Forest Service and the Inland Waterways Commission, to discuss the control of the headwaters of the Delaware River. Enormous damage is done almost every year by floods in that stream and its tributaries. Although the subject is one of much importance, nothing has been done in the past except to make investigations, because the stream is an interstate river and joint legislative action by three States is necessary to produce any effective measures. The conference decided to make a joint recommendation to the legislatures of these States looking toward an inauguration of a combined attempt to solve the problem. It was also stated at this conference that representatives of New York and Connecticut would meet before long to discuss some means of joint control of the Housatonic River, so that the waters of that stream may be made available for the New York City supply. For many years it was hoped that some such joint action could be arranged, for a large amount of water is available in the catchment basin of the upper Housatonic which cannot now be diverted for the supply of the city on account of the uncertainities regarding the legal status of interstate streams. It will doubtless be recalled by many readers that Mr. John R. Freeman reported some years ago in favor of obtaining an additional water supply for the city from the headwaters of the stream, but this project was never seriously considered by the municipal officials for legal reasons, and when the Merchants Association undertook, a few years ago, its investigation of an additional water supply, the same legal reasons were held to debar the Association's engineers from considering the river as a possible source for more water.

The Detailed Cost of various works executed for the U. S. Reclamation Service is kept in itemized form so far as possible, but it appears from the "Monthly Bulletin" of the organization that often the data cannot be utilized because of the lack of definite statements concerning essential or modifying details. The omissions are not the results of poorly kept records, but arise mainly from the failure to elaborate details in compiling reports. In order to remedy this condition, which is so common as to render most cost data of little direct value, a number of useful suggestions have been prepared for the guidance of the engineers of the Survey. First of all, it is necessary to know definitely what expenses have been included in the cost records, and whether all expenses incident to the work have been charged against it. It may not always be necessary to have all of the expenses included in the reported costs, but it is necessary to know whether they have or have not been included. The points on which lack of definite information usually exists are those relative to interest on investment, plant depreciation, preparatory expense and general office and engineering expense. It is likewise important to know the period of construction, inasmuch as the prices of labor, the difficulty in getting material, the nature of the season in which the work is done and other important matters of like nature affect the cost of the work. A statement as to the wages paid for the various classes of labor employed, including the number of hours worked per day, is essential, as well as something concerning the efficiency of labor. It very often occurs in the same class of work that a set of laborers may show twice the efficiency that a corresponding number might in another case. Cost data on any piece of work involving the use of machinery necessitate for their proper understanding a detailed description of that machinery. It is important to know whether one or two steam shovels, for instance, are used on a piece of work, the number of engines and dump cars necessary to serve these shovels, and other details of like nature.



Dredge, Derrick Scow and Pile Drivers.

THE CONCRETE SEA-WALL AT CEBU, PHILIPPINE ISLANDS.

By H. F. Cameron, Asst. Chief Engineer, District of Oriente, Cuba.

The location of the heavy concrete seawall on which this article dwells is at the Port of Cebu, Cebu Island, Philippines. Cebu is 10 deg. north latitude and is within the trade winds. From the middle of December to the middle of May there is a steady wind known as the Monsoon, from the northeast. This is known as the dry season and severe storms are rare. From the end of the dry season to the middle of December the wind blows steadily from the southwest, and during this season occur those destructive storms called typhoons; and also the very heavy rainfall. Opposite the City of Cebu about two miles distant is the long Island of Mactan which protects the Port of Cebu in all parts except that where the present concrete seawall has been built, which part is exposed to the strong southwest winds from the open China Sea. The effects of this as concerns the work will be dealt with later.

In point of importance Cebu ranks next to Manila for these islands, being the transhipment point for all the southern or Visayan Islands. The principal exports of Cebu are manila hemp, copra, sisal, pearl shells, and sugar. Upon the completion of the steam railroad now being constructed by J. G. White & Co., Inc., for this island, the export of coal will be added to the above list, as the line of railroad passes in close proximity to several valuable semi-bituminous coal districts which are at present unworked because of lack of transportation facilities. All exports as well as imports, before the construction of the present seawall, were loaded on cargo boats called cascoes which were towed back and forth as the case might be and unloaded. As these boats could only be used during quiet weather, demurrage cases were of frequent occurrence, handling cargo extremely expensive, and the port in general was one for vessels to keep away from if possible. Because of these reasons the present seawall became a necessity to the port.

The line of this seawall as constructed as well as the plan and sections are shown in the sketches. The length of the total wall is 2392 lin. ft., of which 1150 lin. ft. has a bottom grade of minus 20 ft. (the datum plane being the mean low water level of the Coast and Geodetic Survey), and 1242 lin. ft. has a bottom grade of minus 25 ft. below datum, the grade of the top of the wall being plus 10 ft. in each case, which is also the grade of the reclaimed area of approximately 75,000 square meters. The total cost of this work to the Insular Government was approximately $650,000, which has been recovered by the value of the land thus reclaimed. The assessed value of the unimproved land along the old waterfront for the length of the wall with no shipping facilities whatsoever was $7 a square meter, and the value of the new frontage with up-to-date shipping facilities (the new railroad runs along the water front) is vastly increased, which made the project a good business proposition for the government as well as the salvation for the handling of the commerce of the Port of Cebu.

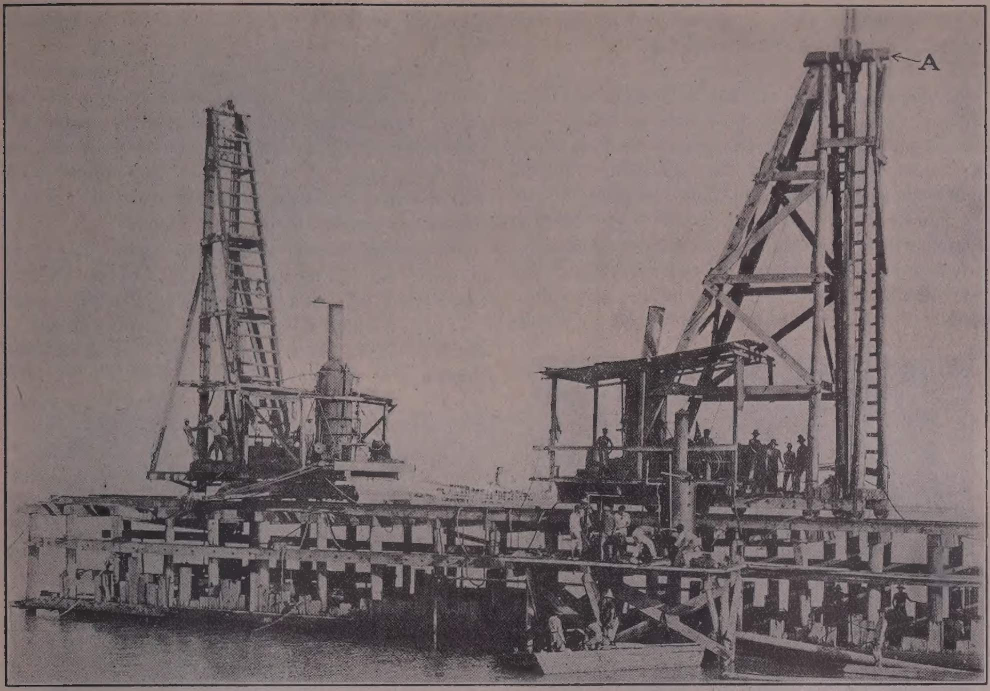
The sketches show the plans of this seawall as designed and constructed by J. G. White & Co., of New York, for the Philippine Commission. This design was suggested after a study of the conditions by Mr. W. J. Mozart, C.E., employed by J. G. White & Co. It is a concrete seawall built on a pile foundation, having a width of base of 18 ft., a total height of 30 ft. in the section *ABC*, and a height of 35 ft. in the section *CD*. Along the center line of wall on 12-ft. centers there are left 6 x 6-ft. holes which were filled with dredged material upon the completion of the wall. Between these holes were counterforts, the dimensions of which can be seen in the sketches. The foundation piles were driven with a batter which increases with the location of the pile with reference to the face of the wall. Bulkhead piles were on 6-ft. centers and carried 12 x 12 in. x 20-ft. caps which in turn supported the temporary construction railroad track for pile-drivers, and concrete cars. The sheet piling used was 4 x 12 in. x 36-ft. lumber to which were spiked 1¼ x 1½-in. splines making a tongue and groove sheeting. This piling formed a continuous bulkhead with an inside width of 18 ft., and was used as the front and back forms for the concrete blocks of the substructure, which stopped at low water. The center forms for the 6 x 6-ft. square holes in the wall are worthy of mention, inasmuch as they were 31 ft. long and were so constructed that they could be taken out and were used over again many times. They were constructed of 3 x 10-in. surfaced lumber. The four corners were firmly made and then locked together by a beveled edge strip to which were fixed at intervals three pivoted bars, 5 ft. 6 in. each, that locked the adjacent corners together. The bars all turned the same way on the pivot and, when ready to take out the forms, could be knocked out one after another from the top, and the opposite strips pulled one towards the other and lifted out; then the opposite corners were treated the same way and removed. Of the six forms used for making over 200 blocks of substructure, only two were lost or could not be wholly removed.

The plant for this contract consisted of the 16-in. hydraulic dredge "America," especially constructed by J. G. White & Co. for its Philippine work, several 6-in. sand pumps, floating derricks, two concrete mixing plants, piledrivers, locomotives, and other plant usually found on such work. Attention might be called to the construction of the piledrivers, which were designed to meet special conditions. All were constructed to run on a 11-ft. gauge portable railroad track, double flanged wheels being used. A 55-ft. revolving piledriver was mounted on a 10-ft. square base or frame and had a 12-ft. overhang. A complete circle could be made inside a minute. The swinglead piledriver was designed to drive batter piles 23 ft. below low water on any angle within the limits of the bulkhead. The leads of this driver were made of 3½ x 12-in. hardwood, protected on the flat sides by ¼ x 12-in. flat iron. They were 75 ft. long and passed through a set of wooden guides which were pivoted on a 12-in. diameter beam marked A in one of the pictures. The hammer used weighed 3000 lb. and with this driver 24 piles 40 ft. long each have been driven in a 10-hour day with their heads at minus 23 ft.

The method of construction of this wall was as follows: A timber bulkhead was first constructed to which were bolted the wales for the sheet piling. As the bulkhead was constructed it was followed along by a floating derrick with a Hayward bucket which excavated inside the bulkhead to a depth of 25 ft. below low water, the bottom being levelled with a 6-in. sand pump. Then came the foundation piledriver placing 16 foundation piles with their heads 23 ft. below low water in every 12 lin. ft. of wall. These piles averaged 36 ft. in length and those that could not be driven to the proper grade were sawed off square by a native diver using a one-man saw and working with only the helmet of the diving dress. These divers would stay under the water for over an hour and saw off four or five hardwood piles a day each. The lengths of the concrete blocks of the substructure were 12 ft. and 24 ft. each, and they were placed alternately, using the sheet piling for the front and back forms and a hinged V-shaped end form. The square center forms were then placed and concreting commenced. The concrete was placed in mass, using one-yard bottom-dump buckets. These buckets were placed on trucks, loaded at the mixing plant, pushed out on the trestle track, lowered to the bottom by a floating derrick, and then tripped. By this method, the best record was placing 530 cu. yd. of concrete with a Ransome one-yard mixer in a 24-hour day. After the substructure concrete had set sufficiently, the superstructure forms were placed in 60-ft. lengths and the wall finished, after which the sheet piling was removed and the trestle torn down. Alsens German cement was used on this contract, the amount being 37,000 bbl. It was extremely slow setting, but tests made on the inside of one of the 6 x 6-in. holes which was pumped out for the occasion six months afterwards, showed that it was so hard and dry a half inch from the exposed surface that a pick had little effect on it and struck fire with each blow given. The concrete proportions used were 1:2½:6, or calling a barrel of cement 4 cu. ft. were 4:10:24, the quantities required to make one cubic yard of concrete.

The gravel used came from a river bed dry eight months of the year and was excavated and loaded into the cars by natives using small baskets which were carried on their heads. A 9-ton Porter locomotive hauled the fifteen 3-yd. cars to the combined screening and mixing plant. The bins for this plant stored sufficient materials for 80 yd. of concrete and the bucket elevator worked fast enough to keep the bins well filled during mixing.

The piles used for the temporary bulkhead were of Oregon pine as they were much cheaper in the longer lengths from 50 ft. up than the native piles, which are difficult to secure because of the fact that all the native piling suited to the work is of hardwood and sinks, and there were no steamers in the islands that had suitable tackle to handle it, and therefore it had to be loaded on bamboo rafts. Six months exposure of the Oregon pine to the action of the teredo was suffi-



Pile Drivers for Straight and Inclined Piles.

cient to make it valueless and so could be used only for temporary work, unless treated with preservatives. The foundation piles were a native timber called bacao, a species of swamp mangrove. They were a dark red colored wood, straight, and had twisted corrugations running their entire length, which with their other good qualities made them a very satisfactory pile. Nearly all the sawed lumber used on the work was from the States. Great watchfulness had to be exercised in storing this lumber because of the white ants, the "anay," that are found in the Philippines. It was necessary to build a platform on posts on the ground, creosoting the posts carefully, then piling the lumber on top of the platform. It was also necessary to paint these posts about every three months in order to keep the lumber free of the white ants.

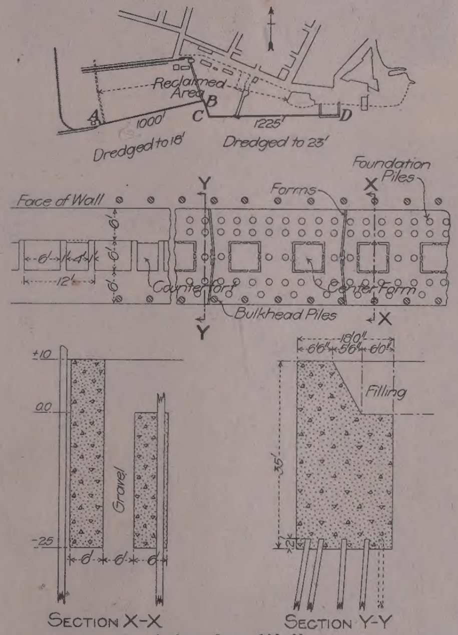
The exposed position for six months of the year of the 1800 ft. of the West part of the wall which faces the open sea, was a great drawback to the rapid progress of the work. During these months it was necessary to work with one eye on the barometer, so that the hydraulic dredge and other floating equipment might be towed out of danger from the quick-coming and disastrous typhoons that are frequent there. On several occasions great damage was done to the bulkhead, which it took weeks to repair. Another difficulty for the contractor during the rainy season was the securing of sufficient gravel to keep the work going. The streets on both sides of the river from which the supply came were narrow and the houses made of grass, so that the locomotive could not run there without taking great chances of firing the whole city, so it was decided to place the railroad tracks in the bed of the river for several miles. The track was chained to trees along the banks and to posts sunk in the river bottom, but even thus firmly secured could not withstand the heavy rush of water that came down this river four or five times during the rainy season.

The labor question on this work was a continual source of worry. The Tagalogs around Manila have had a good training in construction work in the nine years of American occupation, and now make very passable laborers. In Cebu, however the Visayans, who have not the inborn brightness of the Tagalogs to begin with, have had training in agricultural pursuits alone and only a few as dock laborers. Great patience and forbearance had to be exercised in the early stages of the work until they became accustomed to the use of tools, new machinery and its workings. Confidence had first to be gained in regard to the company's methods of payment for work, as in former years they had been defrauded by their own people in this respect and seemed to expect it always. After the natives had mastered the system little difficulty was experienced in keeping regular men on the contract. Another source of trouble are the church holidays or "fiestas" which come very often in addition to the regular holidays allowed by the Philippine Commission. About one-third of the year is lost on Sundays and holidays in the Philippines.

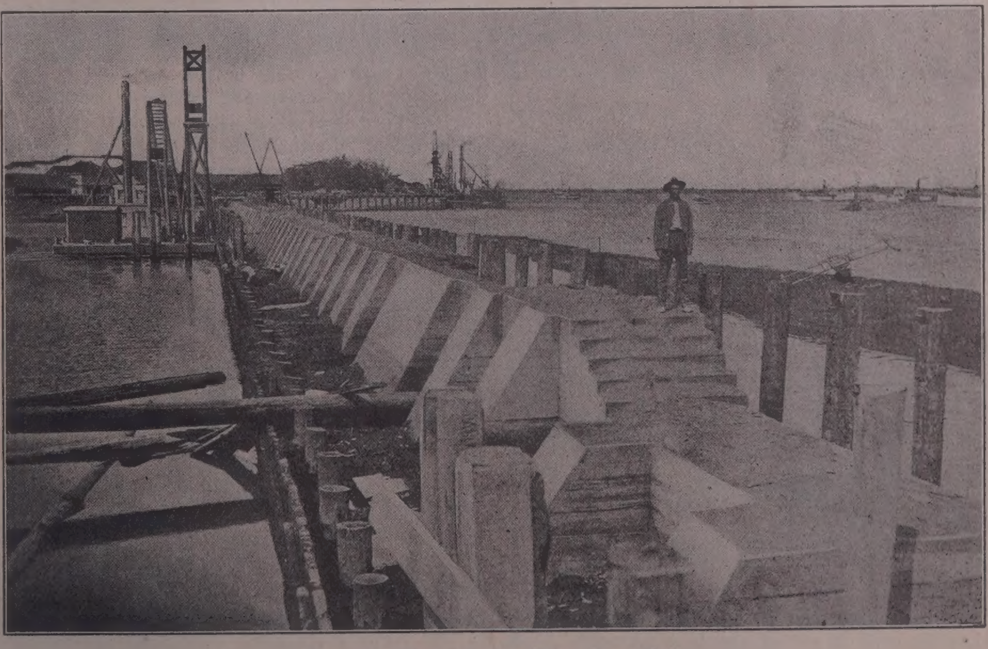
The native diet consists for the most part of rice, maize, and dried fish, and a very little of that as a rule, and consequently they are not overstrong. To be sure that they had a full meal in the middle of the day, the company issued to each laborer in addition to his regular pay, at 11.30 a. m., the sum of five cents. This daily issue was a great drawing card for the laborers and at first the number of them would double on the work about that time.

When the construction commenced all the machinists and hoisting engineers were Americans and Englishmen. Men of this class in the Philippines, whenever they can secure the wherewithal to purchase drinks, make very careless, dangerous, and untrustworthy men to handle heavy work. After putting up with this class of labor for a few months and having the machines laid up for repairs continually, they were all discharged and Tagalogs brought down from Manila to do this work, with a master mechanic to watch the machinery. From that time on there was little or no trouble, the natives making better and more reliable hoisting engineers, and the cost of the work being appreciably reduced.

Another source of trouble which has probably been common to men in charge of work of this nature outside the United States was the careless and shiftless way in which the average exporter of machinery and plant packed his goods for the export trade. All the machinery and other material was packed in flimsy boxes with little or insufficient wire bands or other reinforcement; the small brass fittings on the machinery are left exposed so that the coolies in transshipment ports of Singapore, Hongkong, and Manila are able to steal them, as they do with everything of that nature they can, whether they have any use for it or not; and the goods are carelessly classified in the invoices which are



Cebu Sea Wall.



General View of the Cebu Sea Wall.

shiftlessly sent; all these things result sometimes in the goods being confiscated by the Custom House or a very heavy cash bond is required, which is sometimes held for months pending a decision. This also occasions loss through the long waits that occur in receiving the goods on which the progress of the work depends.

Investigations for the Gatun Dam.

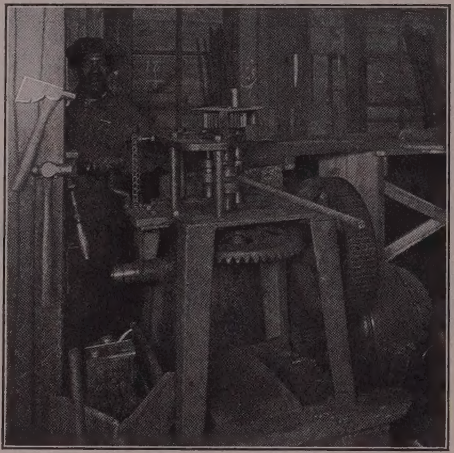
A series of investigations is now being made at Gatun under the direction of Mr. C. M. Saville to ascertain the conditions at the site of the great dam which will form the leading feature of the Panama Canal. The following account of the work was recently contributed to the "Canal Record" by Mr. Saville. The work is for the purpose of investigating the various soils and rocks which will be used in the construction of the dams and also the materials that are found in the foundations and in the portions of the ground underlying the embankments and walls to be constructed. It is expected that these experiments will show clearly the physical characteristics of the materials themselves, and demonstrate their condition when placed in embankments or when forming foundations subjected to excessive loads or heavy water pressure.

The principal investigations are:

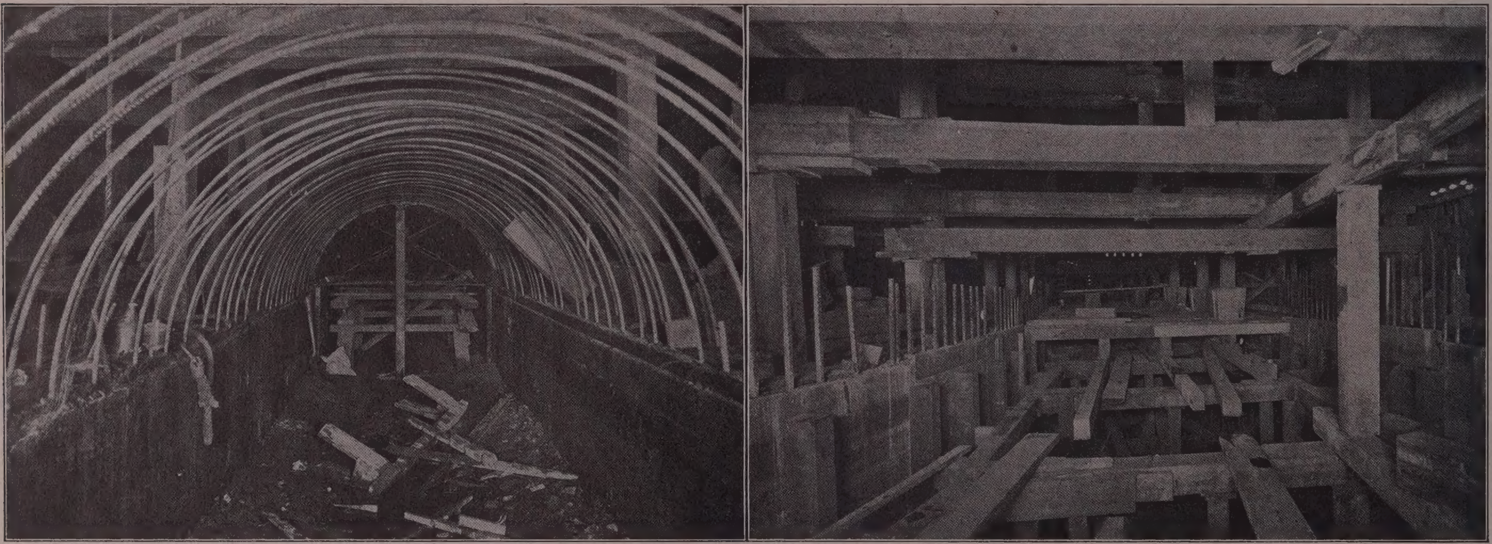
1. Experiments with soils in a wooden tank to ascertain the slope of the water in the embankment; the amount passing through the soil; the best method of depositing soil in order to make it resist the passage of water; and the effect of a load on the embankments.
2. Experiments to determine the frictional resistance of soils and rocks to the passage of water.
3. Experiments to determine the frictional resistance of soils to pressure.
4. Wash drill and diamond drill borings.
5. Test pits in the dam location on Gatun Island and the lower part of the Chagres Valley, and on the hill at the spillway.
6. Experiments to determine the action of the materials under heads of water similar to that expected in the dam.
7. Determination of the best mixture of available materials for making impervious embankments and the action of these mixtures under pressure and when exposed to the action of water.

Beside the borings and soundings that are being made to investigate the material in the foundations of the dam, other investigations are under way for the purpose of developing the location and extent of the best materials from which to construct the big embankment. Thus far the returns are of a most satisfactory character, both as to quality and quantity.

(1) Experiments are being made in a water-tight wooden tank, 80 ft. long, 6 ft. wide and 8 ft. high. In this a section of a dam is being constructed one-twelfth the size of the actual structure. Into the tank materials are being pumped under conditions similar to those that will exist in the dam itself. When completed, the experimental section will be subjected for a considerable period to water pressure and careful records kept of the rate at which water may percolate into the material. These observations will be made by means of glass gauges set up outside the tank at distances of 5 ft. apart, and connected with perforated horizontal pipes with the interior of the embankment. In this way the slope of saturation through the embankment can be determined and the actual dam itself so designed that no water of percolation can find its way to the outer slope until it has lost all its pressure and power of damage. Several dams of various materials will probably be constructed in this tank, from time to time, in order to determine the best materials for use in the actual work.



Bending Machine, Market Street Subway.



Arched Roof of Reinforced Concrete Section and Bracing of Regular Section, Market Street Subway, Philadelphia.

(2) Experiments are being made in galvanized iron tanks about 3 ft. in diameter and 5 ft. high. In these a layer of the material to be investigated is placed and exposed to a constant head of water. Careful observations by glass gauges make it possible to determine the quantity of water that will pass through under various heads of water, and the thickness of material that will be necessary to make the embankment practically impervious.

Studies of the land slides at various points on the Isthmus are being made and experiments made with large size sliding boxes to determine the friction angle and the coefficient of friction for the various materials.

The wash drill and diamond drill investigations are on a much more extensive scale than previously undertaken, and the ground is being so thoroughly explored, and to such great depth, that it is felt that no conditions can obtain that will materially change the plans after they have once been decided upon.

On Gatun Island, at a point about half-way between the old channel of the Chagres River and the French canal, an exploration pit is being excavated, which it is proposed to carry down a distance of at least 100 ft. This pit is 20 ft. square, and has now reached a depth of 18 ft. As yet the materials excavated have been compact clay and sand, containing very little water, a hand pump, intermittently worked, being sufficient to drain the pit. The excavation is being carefully watched, and it is planned every 10 ft., and oftener if the material changes, to make mechanical analyses and filtration determinations.

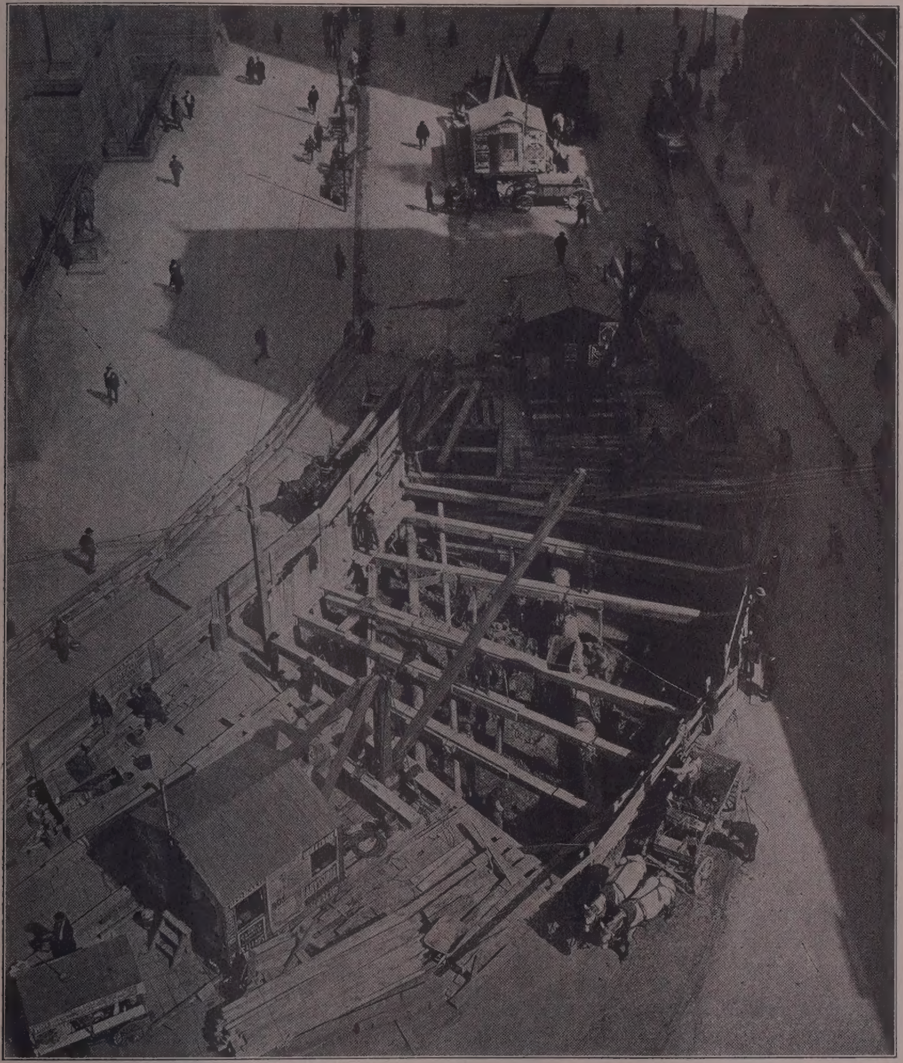
In order to determine the action of the soil and rocks when exposed to heavy water pressure, cylinders of the materials to be investigated are enveloped in strong iron tubes, varying in size from three inches to eight inches in diameter, and then the specimen is subjected to water pressure, varying from 20 lb. to 80 lb. per square inch, corresponding respectively to 46 ft. and 185 ft. head. Abrasion tests are being made of the several rocks found, and also experiments to determine the resisting qualities of the rocks when exposed to the eroding action of a stream of water under pressure.

Beside the ordinary information obtainable from wash and diamond drill exploration regarding the character of the underlying strata, investigations are also being made to determine the velocity of flow of the underground water. These determinations are being made by the electrical method, devised and successfully used by Professor Schlicter on the U. S. Geological Survey work. The underground water conditions are also being investigated by seepage and pumping tests.

Brazilian Railroads in operation at the beginning of last year had a total length of 10,776 miles. In addition there were 1,902 miles under construction and 4,177 miles being surveyed or already approved, making the total mileage about 16,855 miles. The length of line completed last year was 438 miles, of which 69 miles were on the Northwestern of Brazil, 82 miles on the San Paulo & Rio Grande Ry., and 92 miles on the Rio Grande do Sul Ry., these being the heaviest constructors.

The Construction of the Market Street Subway, Philadelphia, Pa.

The Market Street Elevated Passenger Ry. Company's structure between 15th Street, and Delaware River is a reinforced concrete subway, built in general on the center line of Market Street, having two surface tracks on which electric cars are run at short intervals where there is a very heavy vehicular and pedestrian traffic. At the intersection of Broad and Market Streets, the four-track structure approaching from the west connects with two 2-track structures which are run around opposite sides of the City Hall enclosing it with about 2130 ft. of a rectangular loop with rounded corners, and connections to double track present or future lines at right angles to three of the sides at their center points. The tracks on this portion of the structure are laid to permit running trains around the City Hall, thus forming a terminal loop provided with switches, cross overs and one sub-subway, for operating trains in four directions and for separating local and express traffic. The terms "local" and "express" are to be understood as applying to street cars which enter the subway from West Philadelphia and the trains from the elevated railway respectively. This involves large differences of elevation, much curved work and complicated location, thus making very elaborate construction.



City Hall Curve in the Market Street Subway, Philadelphia.

From City Hall to Front St. near the Delaware River, a distance of about 6,000 ft. the subway is of the standard double-track rectangular type with heavy side walls, a flat roof and a longitudinal row of columns as illustrated in The Engineering Record of Oct. 12, 1907. The roof is of reinforced concrete except for an aggregate of 2070 ft. at the five stations where it consists of 5-ft. concrete arches supported on transverse girders and has a minimum clearance of 4 ft. below the surface of the street. The floor is a flat concrete slab 11 in. thick below the concrete which is placed with the track construction, and is at its maximum depth 32 ft. below the surface of the street.

The difficult City Hall section of the subway on Market St., from 15th St. on the west to Juniper St. on the east is officially known as section 5, and was built in open and covered trench. The preliminary work there, necessary before any section or construction of the subway was commenced, included removing to a temporary position clear of the excavation a bronze statue and its granite pedestal, which together had a height of about 25 ft. above the street and weighed 75 tons; underpinning adjacent structures; and the construction of a comparatively small amount of 2 x 3-ft. brick sewer. Operations on section 5 were commenced on Feb. 25, 1906, at the easterly end of the 15th St. station approaching section 5, pits were sheeted down below sub-grade and crib work built in them 25 ft. apart for I-beam needles which temporarily supported the columns of the arcade bridge at the Pennsylvania R.R. terminal station. The needle beams supported the structure until the completion of the subway when they were removed and their loads were transferred to piers on the subway roof.

In moving the bronze statue and its granite pedestal, drifts were made under the base, the monument raised, seated on rollers, moved transversely about 75 ft. to a position near City Hall where it was not in the way of street traffic. After the completion of the subway the monument will be returned to its original position and will be supported directly on the specially strengthened subway roof.

The first subway excavation was made on the west side of City Hall, where a trench 25 ft. wide was opened between the building line and the west rail of the surface track. All street cars were taken off from this part of the loop and were run temporarily on the north side of City Hall, other traffic being diverted from time to time as the work progressed. The trench was sheeted down to a depth of 12 ft. braced and planked over so that traffic could be resumed. The side wall and one row of columns were constructed in this trench for a length of about 150 ft. Afterwards the trench was extended to a width varying from 35 to 50 ft. and both side walls and the center row of columns were built in it simultaneously, completing the cross section of the subway.

This construction was continued around the four sides of the City Hall, for a distance of about 2130 ft. The excavation was carried to an average depth of about 28 ft. and the sides of the trench were sheeted with 2-in. planks driven with mauls as the excavation was made with picks and shovels. The planks were driven in 12-ft. and 16-ft. lengths and were braced with 8 x 10-in. waling pieces and 12 x 12-in. cross struts 8 ft. apart longitudinally and 6 ft. apart vertically. Spoil was shoveled into ½-yd. steel buckets handled by traveling derricks which moved on the wooden deck over the trench and delivered to wagons in the street alongside. Portions of the trench were left open by the omission of a short length of the deck planks and the derricks approached one or both ends of them on tracks of 10 ft. gauge, supported directly by the vertical and transverse bracing in the trench.

The derricks were of the ordinary stiff-leg type with a horizontal platform built on their sills to carry the Lidgerwood and the Maine hoisting engines, all if which were driven by electric motors. The eight derricks installed on this section had 30 and 35-ft. booms of 5-ton capacity and each handled about 60 to 80 yd. of spoil in 10 hr. Ground water level was about 6 ft. above sub-grade in the deep trench where the local loop passes under the express tracks on the east side of the City Hall, but as the flow was moderate, amounting to about 300 gal. per minute it was easily handled by two 4-in. centrifugal pumps driven by electric motors running alternately.

All concrete used on this section was 1:2½:5 except on floor and walls below ground water level where the mixture is 1:2:4 made with Vulcanite Portland cement and stone broken to pass a 1-in. ring and be rejected by a ¼-in. ring. It was mixed by three McKelvey mixers operated by electric motors and located on platforms at street level, from which it was delivered by wheelbarrows to wooden chutes, depositing it as required in the wall forms or in the roof and invert. The concrete mixers were moved as the work advanced, so that the wheeling distance was limited to about 50 ft. on an everage. The constant change in location made it impracticable to supply storage bins or install a gravity system of delivering materials to the mixer and they were brought as required on wagons and handled by hand. The principal quantities involved for this section included about 130,000 cu. yd. of earth excavation, 23,000 cu. yd. of concrete and 2,360 tons of structural steel and 960 tons of reinforced steel. The work on Section No. 5 is being executed by the E. E. Smith Contracting Co.

Section No. 6. about 6,000 ft. long reaches on Market St., from Juniper St. at the City Hall to Front St. near Delaware Ave., and is throughout of the standard double track rectangular cross section, except at the five stations, which have platforms about 350 ft. long on both sides of the tracks. The alignment of the subway is substantially on the center line of the street and its width is about 36 ft. from out to out of side walls. The depth of the bottom of the invert below street level averages about 27½ ft. and varies between 24 and 32 ft. This location interfered with the existing circular brick sewer 5 ft. in inside diameter and about 10 to 24 ft. below the surface of the street to its invert. Before the construction of the subway the old sewer was replaced by two reinforced concrete sewers, one on each side of the street close to the outer walls of the subway. The new sewers are deeper than the old one and have flat, V-shaped inverts, vertical sides and arched tops and vary in size from 7 ft. inside diameter of outfall to 4 ft. at west end of the section near Juniper St.

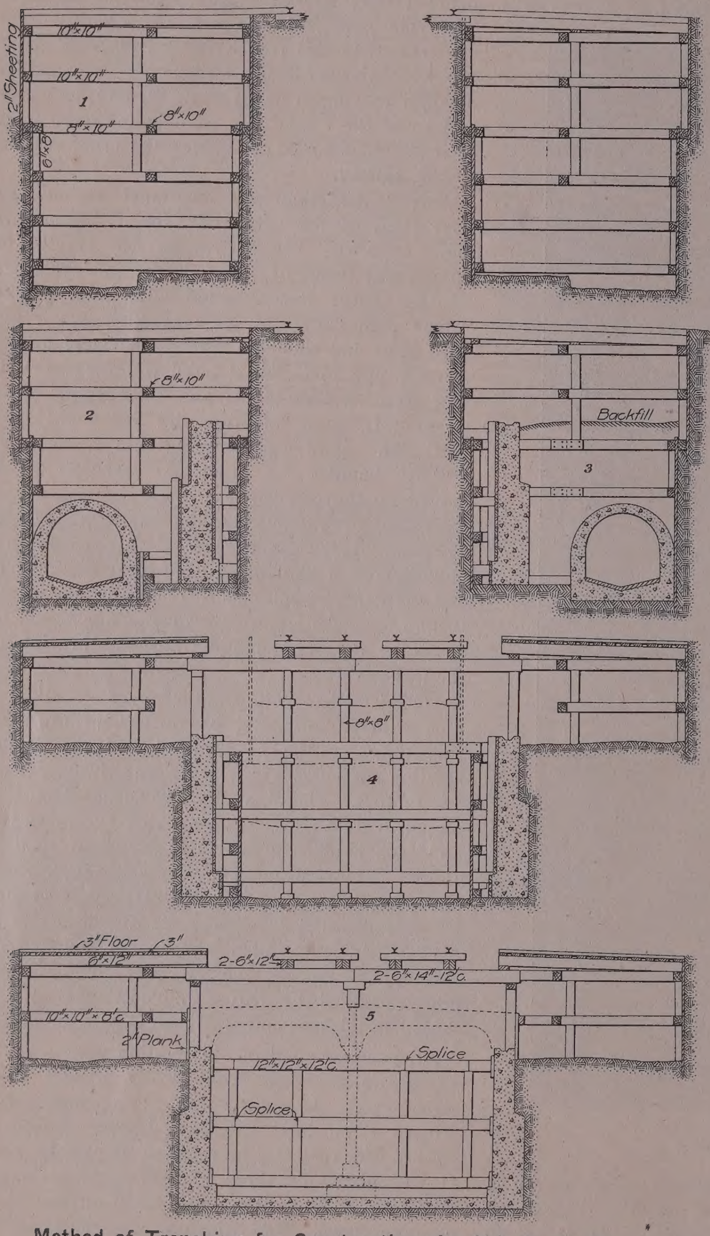
When conditions were favorable the trench was excavated to sufficient width to permit the construction of the sewer and side wall at the same time. When the close proximity of the old sewer made this inadvisable, on account of the danger of breaking and flooding the work, the new sewer was pushed ahead of the subway work to some point where the old sewer could be connected with it. After this was accomplished, the excavation for the subway walls followed without danger of being flooded.

The new sewers were built and connections to the house drains were very carefully made with cast-iron pipes and fittings on account of the vertical drop due to depth of the sewers below the lines of the original connections. The inverts were first laid in the bottom of the trench and on them were set up collapsible steel interior forms around which the concrete was placed in contact with the sheeting which served as permanent exterior forms up to the springing line above which curved boards were used up to the haunches. After the completion of the sewers the side trenches were back filled up to the surface of the street level, and sheeting and some of the cross braces and waling pieces remaining permanently in the ground to support banks and underground structures. The other timber being removed as the backfilling proceeded.

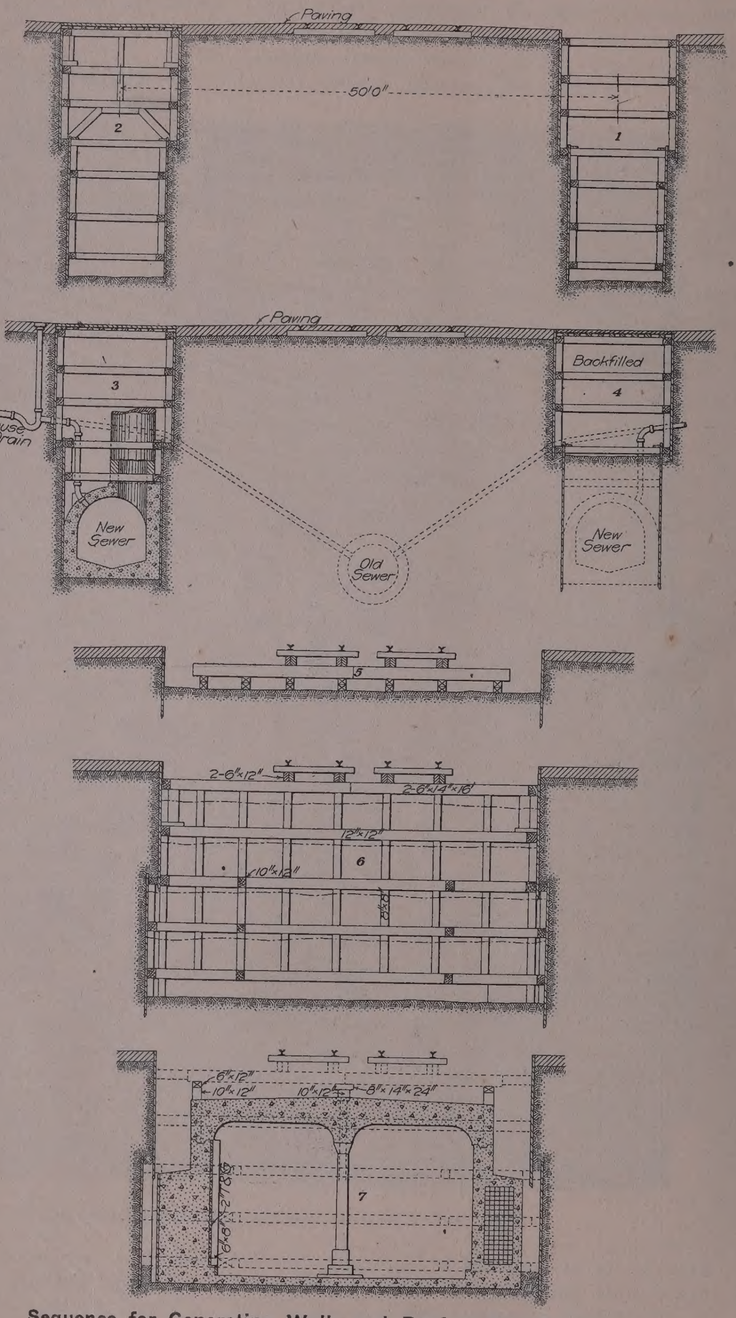
Previous to making the core excavation the old sewer was connected to the new one by temporary flumes and the sections thus released from service were removed with the core.

After the completion of the excavation of the side trenches, the next step was to excavate the core. Before starting this 12 x 14-in. timbers were placed longitudinally under the ties of the street railway tracks approximately under the lines of the rails, to facilitate the underpinning of the tracks as the excavation was carried on below. Posts were placed under these stringers as the excavation deepened, being caught up on short sills or footlocks. Transverse 10 x 12-in. braces, between the 8 x 10-in. waling pieces were placed in position approximately every 5 ft. in depth, the posts supporting the stringers under the tracks being transferred to these timbers after they were placed. This operation was repeated until the excavation reached subgrade. In timbering the trench, false rangers were placed opposite to the rangers against the sheeting, and about 2 ft. from the inner line of the wall to be built, with short braces extending to the outer rangers so that these short braces could readily be removed as the walls were built, the main cross braces transferring the thrust to the walls as the latter were brought up.

After the walls were built the footings for the center row of columns were placed and the columns erected, after which transverse needles consisting of 12 x 12-in. timbers were placed under the longitudinal stringers supporting the ties of the surface tracks, and were spaced 6 ft. apart to coincide with the column locations which are 6 ft. center to center. These needles were in two lengths, the joint being in the middle of the subway, and were supported at their outer ends on posts resting on the tops of the side walls built up to the under side of the fillet at the junction with the roof, and held at the joint in the



Method of Trenching for Constructing the Side Walls First.



Sequence for Concreting Walls and Roof at One Operation.

middle by the permanent steel columns to which they transferred their loads.

When the 12 x 14-in. stringers were placed under the cross ties of the surface tracks, planking was laid upon the stringers transversely between the ties, and between the two inner rails of the adjoining tracks upon which a layer of sand was placed to receive the granite blocks which comprised the original pavement on the street. In placing the planks between the ties, the latter were shifted slightly to make a closed deck to receive a sand bed. Between the tracks where the ties do not extend over the space between the rails, longitudinal planking 2 in. thick was laid to form a closed deck, longitudinal planks also being placed on the ends of the ties exterior to the outer walls. By this method the temporary wearing surface corresponds to that of the original pavement, and avoids the repeated planking which otherwise would be required due to the heavy traffic. This method was first followed on the subway on west Market St., its advantages leading to its adoption for the work on east Market St.

The subway displaced several large mains and conduits which were replaced or shifted as the excavation progressed. One of the most important was a 16-in. high pressure fire service flange jointed water main under 300 lb. working pressure. This was undermined, temporarily supported on vertical shores, and well braced until the work was advanced when temporary connections about one block apart were successively made to the parallel new main just outside the excavation and the successive lengths of the old main were removed to clear the concrete structure, care having been taken to space the bracing to avoid it. The new main was tested to 800 lb. pressure in the shop and 300 lb. in the field and was put in service without any accident, serious difficulty or delay.

A 20-in. low pressure cast-iron water main was replaced in a similar manner. It was feared that the 10-in. gas main, which in most cases was located clear of the subway roof, might undergo settlement or shock sufficient to open the joints during the construction of the subway and cause a leakage that might produce a dangerous explosive compound in the subway. To prevent this, temporary 6-in. mains were laid on the surface of the ground each side of the subway trench, and were connected to the mains at each cross street, forming by-passes and enabling the corresponding sections of the original main to be cut out and remain dead during the construction of the subway, after which the temporary mains were removed and the mains were relaid and restored to service in their former position or were removed laterally or vertically as far as might be necessary. All house and municipal connections were, of course, made to the 6-in. pipes during the period of construction. The 4 x 4-ft. concrete and tile conduit for the Keystone electric ducts was entirely removed and relaid in the backfill. The conduit of the Bell Telephone Co., and those of the other corporations were also rebuilt in the backfill.

Considerable ground water with a maximum head of 5 ft. was encountered and was handled with twelve centrifugal pumps of the Gould, Morris and D'Olier types with discharge pipes from 3 to 5 in. diameter. They were driven by 5 to 12 h.-p. electric motors, of the General Electric, Westinghouse and C. & C. and Maine types.

The material encountered was principally loam, sand, clay and gravel, which was shoveled directly into ½-yd. tilting steel buckets handled by traveling derricks which hoisted them from the trench and dumped them into wagons waiting alongside, three or four bucketsful usually making one wagon load. There were installed on this section 16 traveling derricks, each of them having a 12 x 10-ft. house on a 12 x 25-ft. platform supported by four wheels on a 10-ft. gauge track laid along the line of the trench. The derricks were of ordinary stiff-leg pattern with 6-ton, 35-ft. booms operated and swung by Maine hoists and motors, Lidgerwood hoists and General Electric motors, or Dobbie hoists and Westinghouse motors. About 20 per cent. of the spoil, especially that hoisted at night from the core excavation, was carried back in the line of the work and dumped directly for backfill. Of the remainder a portion of the gravel was carted some distance to storage and afterwards returned for bedding the temporary block paving and the rest, corresponding to the volume of the subway in excess of the required backfill, was removed.

The side walls were built in forms made of 2-in. tongue and groove horizontal boards, planed both sides and fastened together with 6 x 8-in. vertical pieces 4 ft. apart on centers which were blocked against the longitudinal trench braces. The vertical reinforcement bars in them projected above the tops of the walls to bond with the roof concrete. The forms for the side walls were built in sections up to 200 ft. long and the roof slabs were built in sections on fixed centering shored up from the bottom of the subway which was knocked down and rebuilt for successive lengths. The roof was covered with two ½-in. layers of rock asphaltic mastic applied to break joints and smoothed with wood floats. This was covered by a layer of concrete and is considered very satisfactory, the plastic material permitting patching after the removal of the timber posts, as other material would not.

The 1 : 2½ : 5 concrete was made with Vulcanite and Edison brands of Portland cement and was measured with a 100-lb. unit of cement to 2½ cu. ft. of sand and 5 cu. ft. of screened pebbles from ¼ in. to 1 in. in diameter or crushed stone of the same size, when the pebbles could not be procured. It was mixed in seven machines of the Smith and McKelvey type which delivered into wheelbarrows from whence it was dumped into hoppers and chutes conveying the concrete to the required points of construction in the trench. Concrete materials were delivered as required by wagons and were shoveled by hand into the hopper of the mixing machine, or raised by lifting devices operated by the motive power running the mixers.

The contractor's repair shop, smith shop, machine shop and carpenter shop, located near Front St., were equipped with a number of machine tools operated by electricity. A special machine was designed by Mr. Swaab for bending the reinforcement rods used in the sewer. It was constructed on a principal similar to that of the ordinary tire bending machine, but was modified to enable it to bend any curve from 4 to 9 ft. in diameter and could be operated with great precision. The rolls could be set so as to form a tangent on the end of the curve. The machine has a capacity of two 1-in. rods per minute and was electrically driven through a link belt. It was manufactured by the Nazel Engine & Machine Co., Philadelphia. A portable General Electric air compressor was also installed and served to run Philadelphia hammers used for driving rivets and for miscellaneous purposes in construction.

Work was commenced July, 1906, and has been prosecuted vigorously with an average force of about 1,000 men working 9 hr. per day, work being carried on at night during most of the time.

The structure was designed by the Engineering Department of the Philadelphia Rapid Transit Co., Mr. Wm. S. Twining, chief engineer, and Mr. C. M. Mills, principal assistant engineer. The contract for section 6 was awarded to the Millard Construction Co., Mr. S. M. Swaab, chief engineer. The construction work is under direct charge of Mr. F. R. Fisher, resident engineer for the Rapid Transit Co.

The Further Improvement of Our Inland Waterways.

Read by Major C. S. Riché, Corps of Engineers, U. S. A., before the Contemporary Club of Davenport, Iowa.

For many years it was the fashion to ridicule the Government's work of river improvement. While our rivers, so far as naturally navigable, were the highways for the exploration and early settlement of the country, the invention of the railway, and its rapid extension in all directions, soon drew the traffic from the rivers, and the convenience and celerity of the railway as a means of transportation made many believe that river-borne commerce was a thing of the past. So long as the volume of freight to be moved remained within certain limits, the railways could handle it advantageously; but the volume of freight kept increasing with the increase in density of the population, and the railways have found themselves more and more taxed to take care of the business that was offered them.

The development of railway transportation since the year 1880 has never been equaled, yet all admit that this development has lagged far behind the increase in our farm products, in the volume of factory productions, in the output of mines, forges, steel and iron mills, and in the enormous increase in our live stock and other industries of the nation. Our domestic and foreign commerce have increased in the last decade so that our railway systems have become admittedly and grossly inadequate for the successful handling of commodities—in their equipment, in their trackage and in their terminal facilities. One cause of this condition is the unexampled growth in our population.

In 1890 the United States proper had a population of 62,622,250; in 1900, 76,303,387, and it is safe to say from the present rate of increase that the 1910 census will show 95,000,000.

It is conservatively estimated that our population, native and foreign, increases each year 2,000,000.

The improvement in recent years of farm and manufacturing machinery and appliances has quadrupled the capacity of labor, and the inventive genius of the American people has not yet been exhausted. Other improvements will come in the future as in the past.

In 1890 the value of the farm products of the United States, not including live stock, was $2,460,170,454; in 1900, $4,739,118,752, an increase in ten years of approximately 100 per cent. The Secretary of Agriculture in his annual report for the year ending Dec. 31, 1906, gives a total value of $6,974,000,000, an increase in fifteen years of approximately 300 per cent.

The bulk of this increase in farm products has been in the West, South and Southwest. It is a matter of familiar knowledge that until recent years the live stock of the Southwest, seeking a market, were driven on foot. Now almost universally they are shipped by rail.

In 1890 the value of the manufactured products of the United States was $9,372,378,384; in 1900, $13,010,036,514; in 1905 it is officially stated that it reached $14,808,147,089, an increase in fifteen years of approximately 60 per cent.

The present period of depression is but a temporary set-back—a breathing spell—and will assuredly be followed by a still greater development of all our industries.

The capacity of our railways is seriously taxed to meet the requirements of this commerce, and the vast extent of this rapidly growing traffic is one cause of the congestion which has confronted the railways. Eminent railway experts state authoritatively that it will require an expenditure of over a billion dollars, five years of time, and the services of two hundred thousand additional men to render the railways of the United States adequate to the handling of our commerce as it exists to-day. They further state that while the money might be obtained, the additional labor cannot. In the last ten years our industries have increased in output fully 100 per cent. During the same period the railways have increased their equipment and facilities for handling the internal and foreign commerce of the United States about 40 per cent.

The inability of our railway systems to handle the great and growing traffic of the country has caused attention to be again directed to the inland waterways as a means of increasing our transportation facilities. The energetic interest of President Roosevelt has been enlisted, and he has appointed a commission of distinguished membership to consider and report upon the entire question.

The problem which presses for solution is to devise ways and means of transportation which will carry the commerce, relieve the destructive freight congestion and supply transportation facilities more adequate to our needs. The United States is favored with numerous rivers, most of which can be improved to a navigable condition.

Improved waterways will not only be an effective assistance in the transportation of our commerce, but will also be a most potent regulator of railway traffic in all territory within the sphere of their influence, and by their very nature will accommodate an increasing traffic and afford effective facilities ever ready for taking care of the additional commerce which is sure to arise in the future.

It has been amply shown by experience that the lowering of freight rates by water competition, so far from injuring the railways affected, will greatly benefit them by reason of the increased volume of traffic that is and will be created by the certainty of lower rates.

To improve thoroughly the waterways throughout the great extent of our country will involve a large expenditure. To gridiron the United States with waterways, as has been done very largely in continental Europe, will require time and money. Nevertheless, if we are to support a population approximating in density that of Europe, if we are to get our freight carried at reasonable rates from point to point within our borders, and from interior points to the seaboard, where we must meet the competition of the world, interior lines of water communication must be developed.

Looking at the problem as it presents itself today, the most significant fact about our existing waterways seems to be their lack of continuity. The great lakes and the Mississippi with its tributaries, each form great waterway systems, but they lack direct and adequate connection. In addition to these, we have a large number of detached rivers, boats on which are isolated and cannot get from one river to another, nor to either of the great systems above referred to.

The completion of the Panama Canal will place us in direct water communication with the Orient. In the Gulf States there are numerous rivers which empty into the sea and which can be made navigable during the entire year, as they are free from ice. The improvement of these rivers will regulate freight rates in all of that territory, will obviate freight congestion and put the Gulf States, our cotton planters, wheat and grain growers, in direct and easy communication through the Panama Canal with China, Japan and all the commercial countries of Asia.

In former years the freight congestion, which closed the markets of the Northwest, was relieved by building railways from Missouri points to the Gulf coast in Texas, but such has been the agricultural and commercial development in recent years in western Kansas, Oklahoma and Texas, that a destructive congestion exists in those States which demands relief—and this relief can be afforded by the improvement of such rivers in that section as can be made navigable.

A congestion of freight in one part of the country cannot now be met by a concentration of vessels to care for it. The railways can concentrate their rolling stock anywhere. Our waterways, as they now exist, lack a similar power.

A thorough remedy cannot quickly be applied, but a great start towards it can be made at comparatively small expense. One or more efficient waterway connections could be made between the lakes and the Mississippi. The cheapest can be made at Chicago by way of the Illinois River. The great railway systems which have their termini on the lakes could frequently find relief from freight congestion by way of and through the Illinois River.

In addition to this a coast canal system could be extended, making an efficient and sheltered waterway nearly all at sea level and connecting all the sounds, bays and rivers from Boston to the Rio Grande with each other and with the Mississippi.

The above, with the new Erie Canal and with the St. Lawrence River improvements, would enable a boat on any river on our Atlantic and Gulf watersheds to get to any other river. Isolated waterways, so far as these watersheds are concerned, would then be a thing of the past.

I am of opinion that this could be accomplished in from five to ten years, at an annual expenditure within the amount appropriated and authorized by the last river and harbor act.

Supplementary to this, existing waterways should be improved in depth, etc., where necessary, and navigation extended by locks and dams where commercial conditions warrant. Ultimately, short lines of canal should be built where commerce justified and where large savings in distance would result.

An adequate connection between the lakes and salt water is much to be desired. The new Erie Canal being intended for barges alone, and being suitable for the local necessities of New York State, is felt by many to be a mistake from the national point of view. It is questionable if a ship canal of this length could be used economically by ships as a means of transporting freight; but the special conditions which surround lake traffic and which cause the enforced idleness of our lake fleet for five months every year, would seem to justify careful consideration. For not over ten per cent. increase in cost lake vessels could be made sufficiently seaworthy for general ocean service. If some means existed whereby such vessels could get to the ocean during the winter months, they could all be usefully employed to the exclusion of the English and German ships that crowd our Atlantic and Gulf ports at the time when our great fleet of lake vessels is now lying idle.

If the new Erie Canal could have its locks and such structures sufficiently enlarged and its depth slightly increased to permit these vessels to pass through it when light, it is possible that this work might go far towards rendering a ship subsidy unnecessary as a means of restoring the American flag to the high seas. It is possible, too, that the same result could be attained by means of the lakes-to-the-Gulf waterway from Chicago to the Mississippi, which is now under consideration.

The subject merits careful study, not alone for the reasons above stated, but for the further fact that our Canadian friends are earnestly considering the advisability of building a ship canal twenty-two feet in depth from the lakes to Montreal by way of Lake Nipissing and the Ottawa River. Such a canal is estimated to cost not over $75,000,000, which is less than the amount appropriated and authorized by our last river and harbor act, and would provide an all-British deep waterway from the lakes to salt water. Its construction would make the English tramp steamer as familiar a sight at Chicago and Duluth as it now is at New York, New Orleans and Galveston, and the supremacy of our lake marine might be seriously threatened. These considerations certainly justify careful study in connection with any plan for the future development of our great lake waterways.

The Pacific slope must be considered independently of the rest of the country. Here natural conditions are less favorable. With the exception of the Columbia and its tributaries, and the rivers flowing into San Francisco bay, it does not seem that any extensive systems of internal waterways can there be developed.

Where such a system of waterways can be developed, however, there should be a policy of standardization; just as the railways have adopted a standard gauge and a standard clearance overhead and at the sides, so the waterway system should have standard depth, standard sizes of locks and standard openings in bridges, etc. Such a standardization can be attained but gradually. Where depths are to be obtained by dredging or similar methods, a gradual increase can be had without waste. Where permanent structures, such as locks and dams, are to be built, however, they should be built to standard dimensions from the start to avoid any necessity for reconstruction.

The choice of standard dimensions for such structures is somewhat difficult. Locks on the Ohio, where large tows are used, must be wide and long. On other rivers this may be unnecessary or impracticable, but a boat of reasonable size should be able to go through any lock on the entire system, and locks of smaller size than the adopted minimum should not hereafter be built.

As for depth, six feet would seem as small as should be adopted, and there are many arguments for nine feet. Nine feet has been attained on the lower Mississippi—is being attained on the canalized Ohio. Nine feet appears to be the least depth on which can be floated a boat seaworthy enough for occasional lake and ocean service. Such depth would, therefore, give our internal waterways a much wider field of usefulness.

While States and localities should co-operate in the development of internal waterways, these waterways should be controlled, and preferably built and owned, by the United States. No other general course seems practicable, if our waterways are to be formed into a harmonious system.

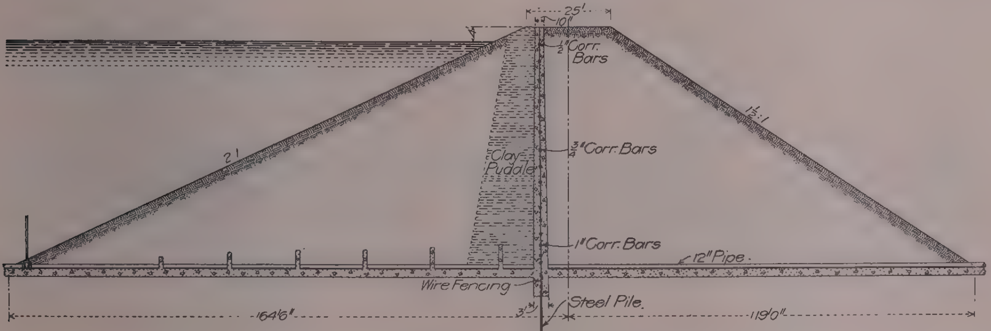
When the benefits of the improved waterways will be principally local it may be that rights of way, easements, etc., for locks and dams and for canals should be furnished to the United States, free of charge by the States or localities particularly interested, and local authorities might be required to build all highway bridges over artificial waterways. There is a tendency to force onerous requirements in such matters when the United States is to pay the cost, and such things can be attended to more economically by local interests. It may also be desirable that the United States should be given ownership and control of all water powers which its structures incidentally develop. The sale of such power privileges for a term of years would often go far towards paying for the work and for the cost of maintenance.

It may be desirable that appropriations should be conditioned upon local authorities providing that wharves, landing places and warehouses should not be monopolized, but kept available for all on equal terms, as the essence of a national waterway system lies in the impossibility of monopolizing it in whole or in part.

The above general considerations concern our waterways from the standpoint of navigation alone and without reference to their relation to the subjects of flood and low water prevention, irrigation, the national defense, etc.

With regard to these matters, that of irrigation seems furthest removed from navigation, so far as possible co-operation is concerned. As a rule, territory requiring irrigation is far removed from navigable water. The great floods which occur in our navigable waterways come almost entirely from precipitation elsewhere than in the irrigation territory. The storage of water in this territory, therefore, will only in exceptional cases be likely to have any appreciable effect in lowering flood heights in the navigable portions of the river, and probably no effect in preventing extreme low water.

Water storage as a means of keeping river fluctuations within bounds is highly desirable, and should always be encouraged. Probably no better opportunity for such storage is offered than in the case of the Upper Mississippi River and its tributaries. The natural storage of water in the watershed of the Upper Mississippi is very great. If all the lakes in this watershed were tinted blue on a large scale map, it would look as if they had been put on with a spatter-brush. As a consequence of this, the range of the Upper Mississippi between high and low water is relatively small, being from twelve to twenty-two feet. Could the discharge of the river be made constant, a permanent stage in water service and a practically permanent condition of river bed would result. The improvement of the river for navigation would then become very simple. But such a state of affairs would be of great benefit, not merely to navigation and to agricultural and commercial interests along the river banks, but also to the great water powers that could be established on the main river at Des Moines rapids and at Rock Island rapids, as well as to all water powers on the tributaries of the river where the same conditions were fulfilled.



An Earth Dam with a Reinforced Concrete Core Wall, at Dixville, N. H.

This result would be of great financial value to all such water powers. On a stream of fluctuating discharge, it is the low water flow that counts for water power. In many cases this is supplemented by pondage or storage of water immediately above the power plant—this stored water being used during the hours of heavy load and stored during the hours of light load; but such an arrangement will not have appreciable effect on seasonal fluctuations in the river flow, and as a result most water power plants are limited in extent by the low-water flow of the river, and depend upon auxiliary steam plants to care for their business during the low-water period. Extreme high water, by flooding and drowning out the dams, etc., also frequently causes interruption in water power service.

The production of a steady flow in a stream, therefore, becomes of very great value for water power purposes. It means the doing away with expensive auxiliary steam plants, and in many cases would permit water powers to be developed that otherwise would be financially impossible.

In the Upper Mississippi watershed, if such artificial storage of water and regulation of its flow as could profitably be undertaken at the cost and in the direct interest of water power owners alone, were so undertaken, I am of the opinion that a very great improvement in navigable conditions would result in the main river as well as in many of its tributaries. Extreme floods would become less frequent, extreme low water would be prevented, and a great approach to a steady flow would be made. The injurious effect upon river flow of farm and swamp drainage and of the cutting off of the forests would be very much more than counteracted.

As a physical problem, there is no serious difficulty in bringing about such a result; nor would the cost of the work be excessive when compared with its value. A lake can be used for storage of water without raising its surface above the level it naturally has at the wet time of the year. Regulating works can be so designed that the water of the lake may be drawn down instead of stored up. Flowage damages can thus be avoided, and while the owners of the riparian rights on the lake might claim damages for the occasional drawing down of the water, such damages, if obtained, would necessarily be far smaller in amount than would be damages for flowage, owing to raising the lake above its natural high water level.

The result that could thus be obtained with the Upper Mississippi and its tributaries, so far as the physical work is concerned, may be difficult to provide for under present local, State and national laws. It may be hard, also, to get the necessary co-operation among water power owners, but the resulting increase in wealth to the whole section of country concerned would seem to make an effort in this direction worth while.

The national interest in the matter, from the standpoint of navigation alone, is very great, and it may be possible by reason of this interest to apply, without cost to the Government, its power of eminent domain, especially if at each water power dam a site for a lock, etc., were to be donated to the Government.

Storage of water, as thus proposed, being always beneficial to river flow, should be applied wherever practicable, but it is doubtful if there are any other rivers in the country that offer such opportunities in this direction as does the Upper Mississippi and its tributaries. The Ohio probably needs such a regulation of its flow far more than any other of our rivers, but such opportunity for regulation as exists with the Upper Mississippi here seems to be lacking. Systematic forestry would help greatly, and, indeed, for the sake of creating a permanent supply of lumber, this should be resorted to at and about the headwaters of all streams, and, where possible, along river banks and on the rights of way of canals, railways and highways.

The Two Nile Bridges which the Egyptian Government is shortly to construct at Cairo will be carried on piers founded on pneumatic caissons, the cutting edges of which for the larger bridge will rest about 93½ ft. below low water level and about 55 ft. below the river bed. The material to be encountered, as shown by borings, consists of alluvial mud and sand of varying fineness. The longer bridge, over the main river, is about 700 ft. long, and consists of six fixed and one bascule span.

An Earth Dam with a Reinforced Concrete Core Wall, at Dixville, N. H.

By Arthur W. Dudley, Manchester, N. H.

There is now under construction at Dixville, N. H., an earth dam with a reinforced concrete core wall, founded on a gravel bed of varying quality and extending between two gravel moraines. The length is about 500 ft. and the maximum height above the base about 76 ft. The location is about three-fourths of a mile west of and below the celebrated Dixville Notch and on the property of the Dixville Notch Corporation. The stream to be dammed is the Notch Meadow Brook, the principal tributary of the Mohawk River, itself the largest branch of the upper Connecticut.

The purpose of the dam is to create a pond varying in depth and covering over 100 acres to be used by the above corporation, who own and manage the "Balsams" Hotel property, for a pleasure and fish pond and, incidentally, for power purposes. An earth dam of smaller proportions than the present structure had previously, in the spring of 1907, been washed out by the spring freshet and had caused considerable damage in the Mohawk Valley.

The location chosen is a short distance downstream from the dam that went out. The profile along the center line of the dam site shows two levels, each about 250 ft. long, making the dam 500 ft. over all, the bottom of the low level being composed of a bed of washed gravel resting on a foundation of mixed clay and gravel, with pockets of the clear gravel occurring at irregular intervals and varying depths, in fact as unsatisfactory a condition as could well be taken. A careful examination of the valley above and below this location showed no better foundation conditions and a wider valley.

Having decided to construct an earth dam with a reinforced concrete core, it was at first intended to excavate for this core to a depth sufficient to secure a satisfactory foundation, but test pits sunk and soundings made the entire length, showed such a variation in the depth of the gravel and such unsatisfactory conditions that it was decided in the lower level to excavate a trench about 6 ft. deep to a foundation firm enough to build the core wall upon, and to begin by first driving interlocking steel sheet-piling the entire length of this lower level. These piles were consequently driven clear across to depths ranging from 10 to 32 ft., the tops being incorporated into the concrete core wall. The latter is 3 ft. thick at the bottom at the maximum depth, decreasing to 10 in. at the top. It is made of a 1:3:4 mixture reinforced with heavy steel wire fencing and by corrugated steel bars. The section shown herewith is taken at the maximum depth of the dam.

The dam shows a cross section 25 ft. wide on top, with slopes upstream of 2 horizontal to 1 vertical, and downstream of 1½ horizontal to 1 vertical. The concrete core is located 3 ft. downstream from the top of the upstream slope.

Assuming the brook level to be 100, the top of the dam is 170, the spillway 165, the bottom of the trench 94, and the high-level bench 135 to 140. The spillway is located at the north end of the high level and will be outside of the dam, partly over a ledge, a location affording no cause for any possible future trouble. A 12 in. and also a 6 in. cast iron pipe is laid through the dam to be used for possible power development and also to drain the pond in a dry time, if it is ever necessary to do so. These pipes are laid on concrete foundations with numerous stop walls of concrete in the upper earth slopes.

A bed of washed gravel and coarse sand of almost the exact desired proportions was located within the limits of the lower slope, sufficient for nearly the whole amount of concrete needed and a Smith mixer was set up close to the wall, and the forms, which were built of inch spruce boards with 2 x 4-in. joists, wired through, were filled with barrows from a platform. The cement used was Atlas, Edison and Vulcanite, largely the latter, and as materials were convenient and everything favorable, a force account showed the concrete to cost about $4.50 per cubic yard in place.

The water used was piped direct by gravity from a higher level. Immediately back of the core wall on the upstream slope is a puddled earth core, 20 ft. thick at the base, battering to 8 ft. at the top, composed of a mixture of clay and gravel puddled and rolled, and the rest of the upstream slope is constructed of the better material found. The lower slope is built of poorer material, but still of fair quality.

The excavation of the bottom and slopes above the dam was done with a steam shovel, and a portion of the high level and lower slopes filled with dump cars from a track which was moved as occasion required. The upper slope of the low level and the puddled wall, however, were filled with scrapers and carts, the carts being filled by the steam shovel and doing much of the compacting in their passage over the earth previously in place. All earth on the upper slope was put in in layers 6 in. thick, thoroughly rolled and compacted. A force account showed this part of the earthwork to cost about 25 cents per cubic yard.

Work on the dam was begun too late in the season to complete it before cold weather, which comes early in October in this latitude, set in and only about two-thirds of the material is now in place. A temporary spillway was arranged, the basin filled to its height and the remainder will be completed early in 1908. The structure when completed will contain 80,000 cu. yd. of earth and about 3,500 cu. yd. of reinforced concrete.

The interlocking steel sheet-piling used was the United States Steel Piling Co.'s pattern, manufactured by the Carnegie Steel Co., Pittsburg. Forty tons of these were used, most of them 12 in. wide, although a considerable number of 6 in. piles were used.

On the higher level, a trench 12 ft. deep developed a solid clay and hardpan foundation and the core wall was started from this foundation without piling. As a precaution, however, a trench 2 ft. deep and 8 in. wide was dug in the middle of this excavation and filled with concrete which was made homogeneous with the wall.

The work was done by the Dixville Notch Corporation, of which Mr. Henry S. Hale is president. Mr. Charles E. Walbridge, of Plymouth, N. H., had immediate charge of the work, doing most of it on the percentage plan. Mr. Arthur W. Dudley, C. E., of Manchester, N. H., made the plans and was engineer in charge of construction. Prof. Robert Fletcher, of Dartmouth College, was consulting engineer, and Mr. Charles H. Chandler, of Concord, N. H., was assistant engineer in charge of the work for the designer.

A Simple Water Softener has recently been built by the Southwest system of the Pennsylvania Lines West of Pittsburg, which consists of a large covered settling tank into which the raw water is delivered mixed with lime and soda ash solutions. A water motor in the delivery pipe actuates a small pump that injects the solutions in the desired proportions. The mixture is then passed slowly through a stirring tank or agitator for hastening the chemical action, the stirring paddles being also operated by the water motor. The mixture enters the settling tank underneath a large bell, from which it rises, clarifies and is drawn off at the top, the sludge being drawn off through drain pipes on the floor of the tank. The apparatus has capacity for 30,000 gal. per hour.

Results of Tar Spraying in Bristol, Eng.

In spraying roads with tar in Bristol, England, the best results were obtained with roads which were in a thoroughly good state of repair, and where the last coat of stone had been laid a sufficient length of time for the surface to have acquired a good face. The results are summarized in the last report of the city engineer, from which these notes are taken.

In the favorable circumstances mentioned the tar penetrated to a depth of ½ in., producing a waterproof skin from which the rainfall rapidly passed into the channels, the surface drying very quickly compared with the adjoining surfaces not so treated. Up to the end of December very little cleaning was required upon any of the roads that had been tar sprayed.

The saving in cleaning is estimated at $500. The saving in hand labor would have been more marked than it was if the roads that were treated had been parts of a group of roads instead of being chief lines of traffic, as it was difficult to reduce the number of men in a gang of sweepers because one road only in the group had been treated. The argument, therefore, is a sound one, that for the most economical application of the principle the roads should be treated in groups, and the orderly system of cleaning adopted in dry weather, so that the light dust blown upon the road, and especially horse droppings, could be picked up at once. Very occasionally the road may require washing, but scraping away the surface as is now done would not be necessary.

Several roads in the St. George district were hand painted with tar, and the effect in reducing the cost of cleaning has been very satisfactory, although the tar lies more on the surface, and does not penetrate the top crust of the road material in the way that tar does when forced through the nozzles in the form of a fine spray.

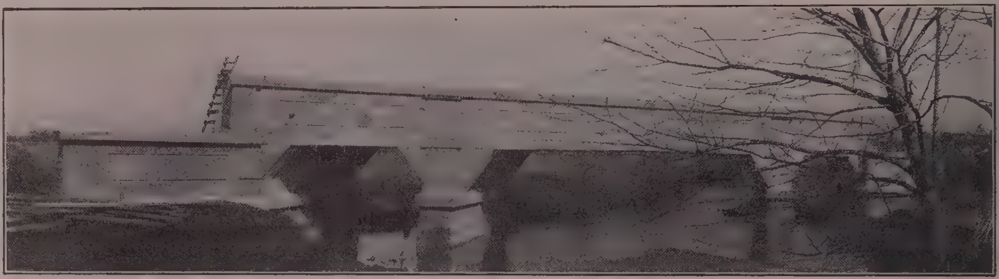
The district surveyors in their reports all agree as to the considerable saving that has been effected by the tar process on the ordinary repairs. With the exception of a short length of Pembroke-road, which required recoating when the tar was applied, and Clifton Park, which has had the levels altered, very few repairs have been made in any of the roads treated with tar. Even in Westbury-road, which would in the ordinary way have required a new coat of stones, a few patchings with tar toppings have been sufficient. The section of Coronation-road so treated was coated in 1907, and the surface is now as good as ever. Under ordinary circumstances a new coating would be wanted in 1909, but if the tar spraying is continued it is not probable that the repairs will be wanted before 1910—effecting a saving of 50 per cent. Taking all the roads treated it may be reasonably estimated that a saving of $1,500 has been effected in repairs, with the consequent reduction of interference to ordinary traffic.

It has been already stated in a previous report that the tarred roads required no watering after the application, with the exception of a few sprinklings before sweeping in front of shops, whereas the adjoining roads had to be watered on eighty-nine days.

The city engineer is therefore of opinion that in all the points to be considered—in the abatement of the dust nuisance, in the less amount of cleaning necessary, and in the reduction of the repairs—the results of the application of tar have been very satisfactory, and that it will be an advantage materially to increase the length of roads to be so treated this summer; also to commence the work as early as possible in order to reap the greatest advantage.

A Reinforced Concrete Cantilever Bridge.

The Indianapolis, New Castle & Toledo Electric Ry. Co., in the construction of its line of 45 miles between Indianapolis and New Castle, Ind., adopted reinforced concrete exclusively for the culverts and bridgework. Altogether, there are 28 bridges and culverts, one of which is of unusual design. It was originally intended to build at this point the ordinary type of through steel truss, but in order to maintain the general character of the bridgework on the line, reinforced concrete was finally adopted, resulting in a design for a reinforced concrete through girder bridge of cantilever construction, with a central span of 60 ft. and two approach spans having a length of 20 ft. each.



A Reinforced Concrete Through Cantilever Bridge.

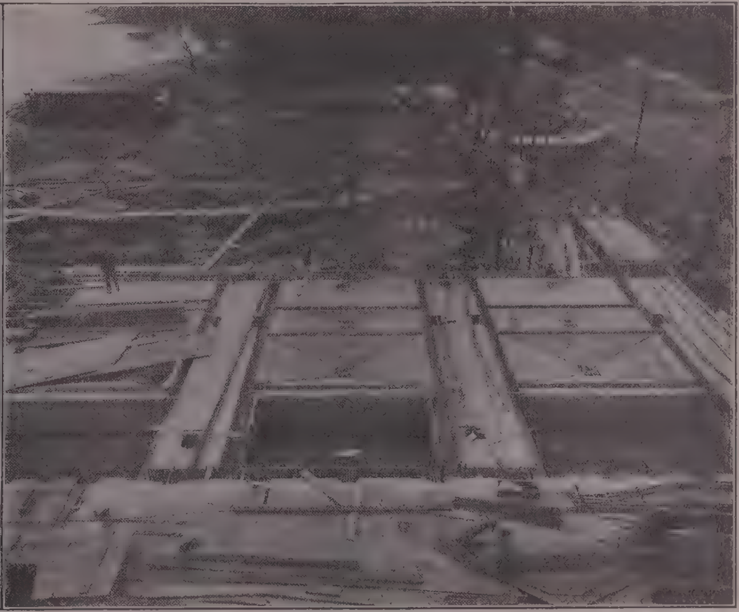
All bridges were designed for Cooper's E50 loading plus 40 per cent. impact and full dead load, with a safety factor of four. The piers of this structure were designed to take the entire load coming upon the structure and were carried down to an excellent gravel foundation, allowing a soil value of five tons per square foot. The anchor arm of the structure is carried down and bedded in the wings of the abutments. The floor slab, spanning 16 ft. in the clear between the girders is 20 in. thick at the center, and reinforced with 1 x 3-in. Kahn bars, spaced 7 in. center to center. The section of the main girders is determined by the size necessary for the central 60-ft. span, and this size is then maintained throughout for the purpose of appearance. The thickness of these girders is 26 in. and the height is 7 ft. No account of the kneebraces was taken in the calculation, but they were added as an additional safety factor and to give rigidity to the structure. The reinforcement of the main girders consist of four 2 x 3½-in., two 1¾ x 2¾-in. Kahn bars, and two 1¼-in. square bars in the bottom flange, and the girders were reinforced for compression in the upper flange by three 2 x 3½-in. Kahn bars and two 1¼-in. square bars. The reinforcing for the negative moment over the piers consists of six 2 x 3½-in. Kahn bars and four 1¼-in. square bars. Throughout the girders, the reinforcement of flanges is connected together by an efficient system of stirrups in addition to the shear members of the Kahn bar. These stirrups are spaced 8 in. center to center. The structure is built on a 39 deg. skew, and the fact of this skew, together with the general requirements of the design, illustrate how desirable concrete is as a structural material where it is desired to mold a complicated structure. The Moore-Mansfield Construction Co., Indianapolis, were the contractors for the entire work.

The Erection of the Westport Power House, Baltimore, Md.

The Westport power house in Baltimore, Md., is a reinforced concrete structure about 466 x 265 ft. when completed to its full dimensions, and will cost about $700,000, without equipment. It is being built in separate independent sections providing for the installation of groups of power units as the demand for them arises. A part of the central portion was first constructed and forms a complete building 110 ft. long, 255 ft. wide and about 79 ft. high over all. It contains a 33,000-h.p., steam and electric plant as described in The Engineering Record of Dec. 1, 1906, and consists of parallel boiler and engine rooms, 48 ft. and 62 ft. wide respectively, as described in The Engineering Record of Feb. 1, 1907. Since the first section was completed in 1906 an 80 x 97-ft. extension has been added to it by the original contractors and they have been awarded the contracts for a second extension 97 ft. wide and 258 ft. long, both of the same general character of the first work. The work now under contract is similar to that already executed and the method of construction will probably conform generally to that adopted in the first case, which will be described in this article.

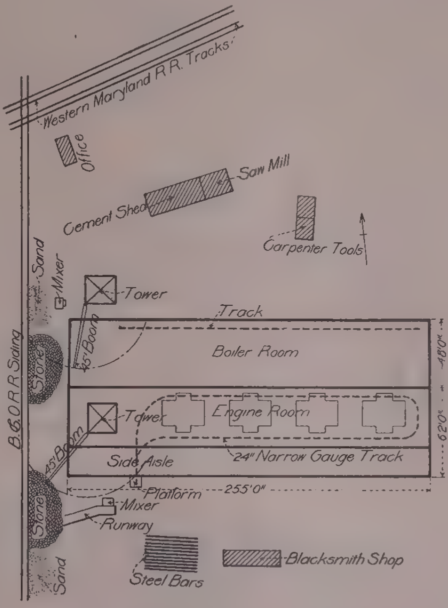
All of the concrete was cast in moulds of the ordinary type made of 1½-in. Virginia pine built up in position and torn down and the materials used again for constructing additional moulds after the concrete had set in the first mould, no attempt being made to strip the moulds bodily or to remove them in complete sections. About 300,000 ft. of timber was required for the centering and moulds, and the structure contains about 6000 cu. yd. of concrete and 750,000 lb. of reinforcement steel.

Lower Part of Walls and Concrete Tower.



Forms for Concrete Ash and Soot Hoppers.

The site was commanded on one side by the tracks of the Baltimore & Ohio R.R., and on another side by the tracks of the Western Maryland R.R., thus providing abundant facilities for the delivery of materials. Alpha Portland cement was received via the Western Maryland R.R. and was stored in a shed with a capacity of 8 carloads. Stone, sand and reinforcement steel were received from the Baltimore & Ohio R.R. and were unloaded by hand from the cars, the former being shoveled into piles alongside the tracks, one pile of each on both sides of the building and the latter being sorted and placed in racks about 100 ft. distant alongside the blacksmith shop. About 20 carloads of stone and about 10 carloads of sand were stored in each pile and transferred as required, a short distance from them to the mixers in wheelbarrows. As it was necessary to transport the cement about 100 ft. to one mixer and 300 ft. to the other mixer, a horse and cart was provided for that purpose.



Location of Construction Plant.

Two 1/3-yd. Ransome mixers were located near the stone piles and were operated by Bullock motors. On the north side of the building the topography was such that the mixer could be located at a level to permit the sand and stone to be wheeled directly to the charging hopper. On the south side of the building a plank runway about 20 ft. wide was provided to take the wheelbarrows high enough to discharge their contents conveniently into the hopper. The mixers were commanded by two rectangular wooden derrick towers, one of which, 20 ft. square and 73 ft. high, was erected on the center line of the engine room just inside the end wall. The other one 22 ft. square and 84 ft. high was erected just outside of the boiler room and each of them had a single 45-ft. gaff derrick boom of 4 tons capacity, mounted on one corner so as to have a clear horizontal swing of nearly 270 deg. One of them was operated by a Lidgerwood, and the other was operated by a Mundy double drum steam hoisting engine.

Both derricks delivered concrete directly to the moulds within their radius and for points beyond it dumped the buckets into four 1-yd. side dump steel cars or deposited them on four platform cars, all of 24-in. gauge which conveyed them to the required points where they were dumped directly into the moulds or on the floor and spread by hand.

The construction was executed with two separate complete gangs of concreters, carpenters, foremen, etc. The gangs worked independently and each contained an average of about 20 men, besides an additional common force of blacksmith and helpers, laborers, clerks and miscellaneous employees. One of the gangs erected the engine house and the other the boiler house, side aisle, and the intermediate wall. About 1000 ft. of 24-in. industrial track with curves and switches was installed for the foundation and first floor work in three longitudinal lines as indicated in the plan, two of which, one for each gang, were raised as the work progressed to the successive height requisite for delivery to the moulds and were carried both on the floor centering and on special scaffolds built for the purpose. The inside tower was removed before the roofs were constructed and concrete for them was advantageously delivered from the outside tower by means of a track carried on trestles built on the boiler room roof.

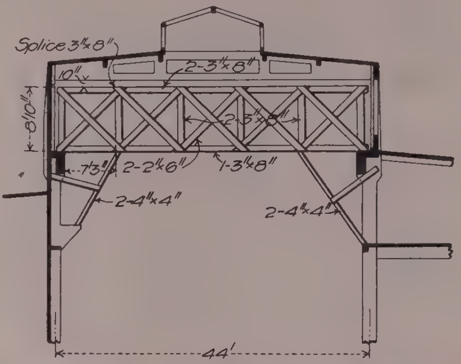
All material for the falsework, centering and moulds was cut on the ground in a sawmill equipped with a band saw and a swing saw operated by a 5-h.p. Bullock electric motor supplied with current purchased from an adjacent plant.

It was at first intended to support the centering for the engine-room roof on falsework carried down to the first floor, but in order to prevent interference with the installation of machinery there, the owners requested the contractor to avoid this obstruction and the latter complied by supporting it on temporary falsework trusses resting on the crane runway girders. These trusses were of the Pratt type, about 9 ft. deep, 44 ft. long over all and 11 ft. apart on centers, and were made entirely of light planks and timbers bolted together at intersections. As no traveler or gin pole was employed in their erection, none of the pieces were larger than could be handled conveniently by two men. The 3 x 8-in. bottom chord pieces were made with a center splice, not here shown, and the top chord pieces were made with two splices and the lower chords were knee-braced at the second panel point to facilitate their erection by the cantilever method.

The knee braces and their center struts were bolted to the bottom chord sections and the latter were hoisted to position and anchored to the runway girders forms from end to end on one side of the building, as shown in the general photograph of the interior. Afterwards the same operation was performed on the other side of the building, the adjacent ends of the bottom chords of the cantilevers were spliced on the center line and the top chords and web members were assembled to them, completing the trusses. Afterwards they were braced longitudinally and the forms for the roof girders were built on their top chords and connected by the centering for the purlins and roof slabs. After the roof girders were self-supporting the falsework trusses were lowered from them.

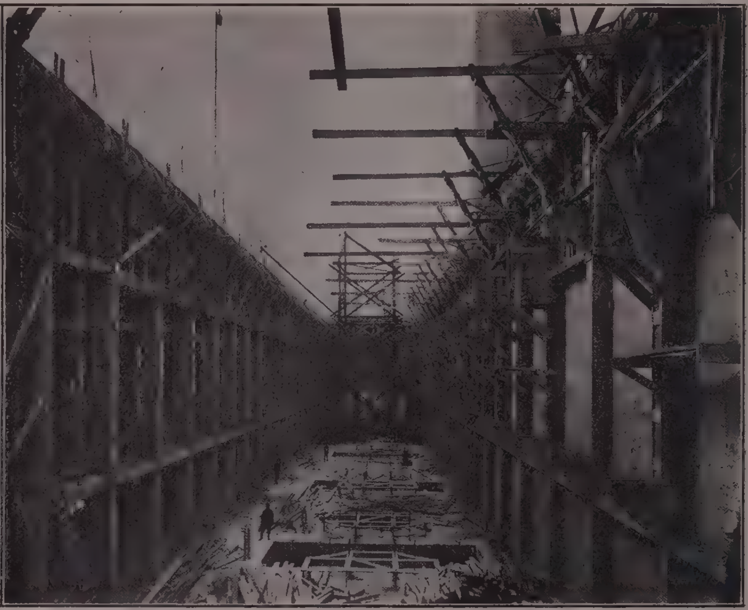
All walls were concreted from the inside and were finished with two grouting coats put on from scaffolds. The first coat was smooth and the second was dashed with a broom. The belt courses, sills and cornices were left smooth and the final appearance of the concrete is uniform and satisfactory. The building was completed in 8 months.

Messrs. Simonson & Pietsch are the architects of the building and Mr. P. O. Keiholtz, consulting engineer for the Consolidated Gas & Electric Light Power Co., owners. The general contractor was the Baltimore-Ferro-Concrete Co., Mr. H. J. West, president; Mr. Henri Kampmann, chief engineer; Mr. H. Massart, designer, and Mr. C. Siquot, superintendent in charge of construction.



Falsework Truss for Erecting Roof Girders.

Concrete Plant, Derrick Towers and Wall Forms.



Erecting Falsework Trusses for Engine Room Roof.

Water Filtration by lateral flow is provided in a gravity plant designed by J. Grant MacGregor, of Goderich, Ont. The filtering material consists of stone and sand of three different sizes in separate beds, placed in concentric rings, the coarsest material in the largest ring. The raw water is distributed by segmental nozzles over the first bed, the drain from which is inward, discharging into the next smaller filtering ring, placed at a lower level. The third ring containing the finest sand is at a still lower level, and discharges into the clear water reservoir occupying the center of the circular plant. This arrangement allows the water to pass by gravity from the base of a higher to the surface of a lower bed. The circular beds are divided by radial walls into units of suitable size for cleaning, provision being made for wash water outlets. The design, which has been patented, is known as the Alpine gravity filtration plant.

Fuel Specifications and Contracts.

By William D. Ennis, Professor of Mechanical Engineering in the Polytechnic Institute of Brooklyn.

In all kinds of trading it is a logical aim to endeavor to pay only for what one gets and to get what one pays for. A commodity of measurable value ought to be exchanged for another of measured value. Even so incommensurable a material as labor is now quite generally paid for "by the piece." All modern commercial establishments test the quantity and quality of materials furnished them in return for an exchangeable value. The steel maker tests and weighs his ore and coke; the paper maker, his wood, bleach and soda ash; the paint grinder, his lead, oil and pigment. Each aims to pay only for what he gets, and he would as soon think of paying without counting out the money as of accepting goods without making sure, by the accurate methods of physical and chemical examination, that they are suited to his purpose.

In these, and nearly all industries, fuel is a raw material of significant cost. In a considerable number of industries fuel is a principal item of cost. Yet of all commodities fuel is still purchased by luck and by guess; passed upon by a fireman who may not know how to use it, and usually by no one else. The largest establishments accept their fuel supply at its face value, paying no attention to quality, and in many cases failing even to check the quantity obtained. The general appearance of a coal is of little value in indicating its merit for producing steam. The behavior of the coal in the furnace of a steam boiler, and the results there obtained, are ordinarily likewise of little value for purposes of comparison, because the conditions are not, and cannot be, maintained truly comparative.

The fundamental unit of value in power production is the heat unit. In buying coal, it is heat units rather than pounds that we intend shall be furnished. It is illogical, then, to pay for pounds or carloads when the value which we pay for cannot be measured on scales. It is equally illogical to pay a high price for a so-called "standard" coal which perhaps has a heat-unit value no higher than that of some other cheaper coal.

The determination of heating value is a simple matter, involving little expense or loss of time. A calorimetric experiment is best, but for anthracite and semi-bituminous coals, computation from the ultimate analysis gives sufficiently close results for comparative purposes. It should be remembered, however, that when coal is regularly received from the same source, frequent calorimetric determinations of heating value may be unnecessary, the proximate analysis alone serving to indicate any marked variations in quality. It is only when two or more dissimilar coals are to be compared that the use of the calorimeter is essential.

Proximate analysis shows the percentages of fixed carbon, volatile matter, moisture and ash. The complete examination of a coal for these constituents often involves serious errors, and the work should be done by an experienced man, preferably the same man each time, in order for the results to be comparative. With regard to the moisture and ash determinations, there is little room for inaccuracy; and as it happens, these are usually the constituents of the first importance as showing daily variations in quality of fuel from the same seam.

Moisture in coal reduces the heating value to a considerable extent, as it takes the place of combustible. Water is expensive when paid for at rates of $2 to $5 per ton. Besides this disadvantage, the presence of moisture results in an actual loss from the heat of the combustible portion of the fuel, since the former must be evaporated in the boiler furnace, carrying away with it its own latent heat when it passes to the stack in the form of steam. It is sometimes asserted that the proportion of moisture is not controllable by the miner. It is controllable within certain limits; it should not be paid for as coal, and if the price of coal is based on a sample containing, say, five per cent. of moisture, the buyer must be a loser when he is called upon to pay the full price for coal containing 10 per cent. Every commodity should be sold with guaranty against adulteration, and if excessive moisture in coal is not to be considered adulteration, a dishonest shipper might with impunity drench each car with water and bill it as weighed while dripping.

Ash, like moisture, decreases the combustible portion of the coal. Its effect is greater than would be represented by its numerical percentage in the fuel. When a certain proportion of ash is reached the coal is practically useless in commercial furnaces; and proportions below this limit result in losses of value which increase more rapidly than the percentage of ash. The determination of the proportion of this constituent is, therefore, of the utmost importance. The character of the ash is also to be considered. A fusing ash not only greatly increases the cost of labor for firing, but is hazardous to good steam service and detrimental to efficiency of combustion. Almost any percentage of water may be permitted in coal, if the price per ton is commensurately reduced; but there is a limiting percentage and quality of ash beyond which the coal would be dear at any price.

This limiting percentage should be based on the dry coal weight. When based on the weight of coal as received, a curious result may follow. For example, in one contract, the moisture was specified not to exceed 17½ per cent. and ash 14 per cent. of the weight of coal as received. As it happened, one large shipment was found to show, moisture 14 per cent., ash 14.5 per cent. Upon raising the question of rejecting the shipment because of the excessive ash, it was suggested that by playing a hose on the coal pile it could be made to conform to the specifications. This was correct. By adding 3½ lb. of water to each 100 lb. of coal, the percentage of moisture would still be under the specified amount, while the percentage of ash in the total would be reduced to 14. It should not be possible for the shipper to comply with specifications by further decreasing the quality of the fuel; so that the percentage of ash must be based on dry coal. A similar argument applies to specifications limiting the percentages of sulphur or volatile matter.

Sulphur is a combustible of low heating value, and its presence in a coal consequently reduces the heating value of the latter. The objection to sulphur arises less from this cause than from its detrimental effect on grates and boiler surfaces, which are corroded by the action of the gas from burning sulphur. Almost all fuel contracts arbitrarily limit the sulphur to a small proportion, usually from 1 to 2 per cent. No coal exceeding the latter limit can be considered a good steam coal, but percentages as high as 8 have been permitted in gas producer practice, without detriment to the producer. Specifications limiting sulphur are readily conceded by coal shippers, who would scarcely attempt to sell for steaming purposes a fuel which was undesirable in this respect.

The determination of volatile matter is of importance. The percentage of such matter serves to classify the coal. Upon its classification as hard, soft or semi-soft, depends the economical aspect of special design in boiler furnace and setting. When the design is made for a stated kind of coal, a different grade cannot be burned economically. The determination of the quantity of volatile constituents serves to establish the suitability of the coal for the plant. In ordinary practice, as the volatile matter increases, the boiler efficiency decreases, and smoke production becomes more objectionable and incessant, especially if the boilers are overloaded. A sharp limitation of volatile percentage is therefore common. While it is true that with appropriate devices and proper operation, smoke can be abated, this is always a matter of difficulty and complexity, and can only be simplified by keeping the percentage of volatile matter as low as possible. In sections of the country where only highly volatile coals are obtainable, however, the establishing of a limiting percentage is of less importance. So far as actual heating value goes, this is slightly increased with increasing percentages of volatile matter. To this extent, the heating value is not an accurate measure of the value of the fuel, and its actual value is to be gauged by consideration of the heating value and of the modifying influence of excessive proportions of volatile matter on boiler efficiency and smoke production. Practically, then, specifications should establish a standard heating value with a fixed maximum limit for volatile hydrocarbons.

The percentage of fixed carbon, as obtained by proximate analysis, checks against that of volatile matter and classifies the coal. Its determination costs practically nothing, and is fundamentally necessary to calculations of heating value based on analysis. When the heating value is determined by calorimeter, the only object of determining fixed carbon is to provide a check on other figures.

The constituents which have been listed are those most essential to determine. Various other tests may be applied to specific fuels. The size should be measured when buying graded coals. The various anthracite steam coals, and the graded soft coals, are classed in established sizes, and it is a simple matter to check the receipts in this respect. The freshness of the coal is sometimes considered, since weathering changes the heating value and the tendency to spontaneous ignition.

Determination of the heating value of a coal by actual trial under the boiler is a delusion. Chemical and physical tests are ample to demonstrate the relative fitness and value of coals in producing power. The idea that undefinable variations exist in coals having identical physical properties, and that such variations affect the performance of the boiler, is an hallucination. Every one knows, of course, that even on the basis of equal heating value, Illinois coal gives poorer results in a boiler than Pocahontas, but the reason for this is ascertained far more quickly and cheaply by proximate analysis than by burning the two coals under a boiler. The only requisite is that tests be intelligently made and that only such coals be considered as are by their grade adapted to the general type of boiler furnace installation. The steam boiler is not an instrument of precision, and when it is used to measure fuel values, its results are far from accurate. Even under expert supervision the evaporation per pound of coal in a single test may not correspond with the known heating value of the coal. With absence of costly skilled supervision, results of tests of this kind are absolutely unreliable. The conditions are not comparative; the modifying influences are not eliminated so as to give each coal its best chance. Further, such a method of testing requires much time, far heavier expense than laboratory experiments, and some risk of interruption to service from the plant. The only reliable figures that can be obtained from boiler performance are secured when a new coal is placed actually in service, replacing the old, and the cost sheets analyzed periodically to ascertain the result. This is experimenting on too large a scale. It is gambling with the whole capital, instead of with pocket money. It is much cheaper to pay the bill of a chemist.

Resorting, then, to laboratory tests as being preferable to actual trial under boilers, the importance of a correct and economical system for sampling and testing is evident. The samples tested must represent the average of the entire amount received during the desired time, usually one day. It would be too expensive to "quarter down" the entire boat load or car load. Where handling machinery is used, an automatic device may be provided whereby one out of every hundred buckets, for example, may be diverted to the sample pile, or a small quantity of coal may be taken form each bucket. With manual methods of moving the coal, representative samples may be obtained if a proper method of selecting is adhered to. A small quantity can be taken from each wheelbarrow or cart load. Whatever the method, it should be based upon the principle of having the coal divided into small unit lots—a conveyor bucket or a wheelbarrow load—with a small sample taken from each lot. This is far better than trying to select a sample, say, from a bin containing a thousand tons. The ideal sampling would be to have a continuous fine stream of coal passing from some point on the line of conveyor buckets to the laboratory. This condition should be approached as closely as is possible in practice. A sample of considerable bulk will thus be obtained, which should be reduced under the direction of the laboratory. The laboratory department should also take charge of the entire operation of sampling. The reduction of the bulk sample by quartering, crushing, etc., is now conducted in or under the direction of the laboratory, and the calorimetric, chemical and other tests made.

The question of weights is possibly in some cases of as much importance as that of heating value, in preparing specifications. In some sections of the country coal is sold on "mine weights" only, and claims for shortage upon arrival at destination amount to nothing. Many of the smaller manufacturing plants are of course not equipped to weigh a car of coal. In such cases a check upon the billed weight may be obtained from the railroad track scales. Checking by estimating the bulk contents of a car is better than nothing. Large plants usually have track scales, or scales for weighing the buckets of coal from the boat. The automatic coal scales commonly used in important installations cannot be employed to check the weights of fuel received unless the daily receipts are being passed directly to the bunkers over the boilers for consumption. In all cases, the purchaser is entitled to the weight for which he pays, and if the weight is short or over he should make settlement accordingly, with provision for demonstrating the correctness of his own weights when called upon to do so.

Automatic coal scales should be adopted as a standard feature of power house equipment. Disregarding the value of a daily comparative record of fuel consumption from an operative standpoint, they serve in general to align power production from fuel with other industries by permitting an accurate comparison of the consumption of raw materials with output. In one device of this kind the scales weigh automatically, record the weight, may be set automatically to stop when an assigned quantity has been delivered, are made of all capacities from 100 lb. to 6 tons per "batch," may be mounted on travelers so as to discharge in turn to various units of a battery, and they operate quickly. They are usually motor-driven and consume a trifling amount of power. The automatic principle may also be applied to track scales, an autographic device totalling the net weights of several cars having uniform tare weights. A similar scale may be attached to a traveling crane, weighing out material of any kind at any desired point under the crane way.

In applying an automatic scale in a power plant it should be remembered that coal measurements, to be useful, must be checked against measurements of power produced or water evaporated. The scales must therefore be usually placed so as to measure the coal supplied to one unit or one battery. In some cases this leads to the use either of a number of scales or of a sliding scale mounted on a trolley, which is carried to different points in turn. Further, as it is desired to measure the coal as burned, the scale must be placed below the bunkers, between these and the boilers. In most cases this means elevating the bunkers, and results, therefore, in a higher and more expensive building. As a substitute method, the coal may be weighed before it is delivered to the bunkers. The latter are then divided transversely into separate bins for each of the boiler units, and by estimating the comparatively small quantity of coal in a bin at the beginning and end of the day, and by noting to what bin each scale load has been delivered, a daily record of the coal fed to each boiler is made possible. The same result could be obtained, of course, by a non-automatic scale, but at much greater expense and difficulty.

A more vital question even than that of weights is the one of deliveries. The strike exemption clauses and other relieving stipulations in coal contracts are the most sweeping of any that the power producer has to consider. After all is said and done, the delivery of coal under contract is almost always uncertain. This is largely due to industrial conditions, which can be remedied only in course of time; but even at present many buyers are meeting with success in eliminating unreasonable clauses of exemption. For example, a shipper should not be relieved from the obligation to deliver because there is a strike or flood in a competitive mine, permitting him to obtain a higher price for his coal; nor because of many other contingencies covered in sweeping strike clauses. A purchaser should not be deprived of his fuel because a railroad company chooses to lay piratical hands on it. No "strike clause" is fair except the one common to all industries, exempting from delivery in case of a crippling strike in the works of the seller himself, and even such clauses are logically unjustifiable. It is a question, also, whether omitted deliveries during a strike should not be made good thereafter at the buyer's option.

One of the most serious effects of interrupted deliveries, whether by labor conditions or transportation conditions, is the resulting abandonment of all effort to hold up the quality of the fuel. When a coal famine exists the standard fuels command so high a price as to be diverted, while the buyer who under contract is entitled to those fuels is thankful to take whatever he can get. It is well to err on the side of leniency; but under evidence of such preferred sales a defaulting shipper should be punished to the limit.

The cost of a systematized method of coal purchasing is not great. In large works the sampling and laboratory work may usually be conducted in connection with the other duties of the staff chemist. Even when outside analysts are consulted, the expense is small where a daily or weekly regular report is arranged for. Contracts must make provision for arbitration when an analysis or other result is disputed, the expense of the analysis to be borne by the party at fault. The method of sampling should be carefully provided for in the specifications, samples should be preserved for a stated length of time and the sample taken as provided for should be the only sample recognized. A part of each of such samples could, of course, be furnished the seller if desired. All sampling should be done at the point of delivery of the coal.

The contract should stipulate a fixed price for standard coal with limiting percentages of volatile, ash, moisture and sulphur and a minimum limit for heating value. Within the limits a premium should be paid for heating value in excess of standard and a forfeit imposed for heating values below standard. Both premium and penalty should be arranged on a sliding scale. This is by far preferable to rigid specifications and a fixed price, since there is no tendency then in times of shortage to accept fuel slightly below standard grade.

There are many objections raised to the purchasing of coal on specifications. Certain natural objections emanate from the sellers. They claim that they cannot control the quality of the coal; that it costs them so much to dig it out of the earth and they ship it as they find it. Does a slate quarryman expect to have his product valued like Carrara marble? An objection perhaps more logical is that the shipper can sell his coal anyway and does not care to become entangled in elaborate contracts. This is too true. The price of anthracite is increasing and the production of soft coal is not keeping up with the demand. The balance of trade is in favor of the shipper. But it should be remembered that in purchasing coal to specification the buyer is not seeking to get something for nothing; he is not trying directly to get more heat units for a dollar and certainly not more pounds of coal for a dollar. He is simply endeavoring to eliminate variations in what he does get for his dollar and to pay for what he actually gets. When he draws up his specification he knows, or should know, what he can afford to pay for coal of the average grade which he has been getting. He is willing to pay the market price for this and a better sum for better coal. On the other hand, he asks the shipper to take less for inferior coal. This is fair and costs the shipper nothing. Where a flat price and flat heating value are named in the specifications the arrangement is not fair and the shipper must quote a sufficiently high price to insure himself against losses due to the rejection of the coal. The buyer, of course, pays this insurance, and consequently loses. But where the sliding scale is employed there is no reason why competition should be restricted on contracts for the supply of coal to specification. It has been reported that one buyer who inaugurated a system of purchasing to specification was obliged under a sliding scale contract to pay double the former price for one lot of coal. If this is true, it furnishes an extreme instance of inaccuracy in determining the average quality prior to drawing up specifications and of a poorly framed contract, but it shows also that coal specifications do not necessarily injure the shipper.

With clear-cut contracts regarding delivery the purchaser may know what his chances of securing coal will be under abnormal conditions, and is then in a position to decide as to necessary provision for storage. To be without storage is ruinous, and to provide abundant storage is almost ruinously expensive, not merely on account of the cost of handling, but because of the loss in quantity and quality of fuel. Where cessation of deliveries is in default of contract such expense should be charged against the coal shipper.

From the buyer's standpoint while the purchase of coal to specification may only slightly, if at all, reduce the coal cost per unit of output, it has the overwhelming advantage that it eliminates variations in the cost of his prime material of consumption. No business is well administered in which there is a lack of definite responsibility for any element of cost, and in the average industry, as coal is now purchased, no individual is fairly responsible for the cost of fuel or of power. This removes a definite standard of efficiency from the engineering force and leads to imperfect operation. In one large plant the coal varied in heating value from 12,700 to 14,300 B.t.u., and in percentage of ash from 8 to 12. There was a considerable production of smoke and some difficulty in maintaining steam at times. By adopting a specification limiting ash to 9 per cent., volatile to 21 per cent. and sulphur to 1½ per cent., with a sliding scale of prices, based on heating value, all troubles were eliminated, the price of coal per ton advanced about 5 cents, the heating value about 2 per cent., and the curve of coal cost per unit of output became a straight horizontal line.

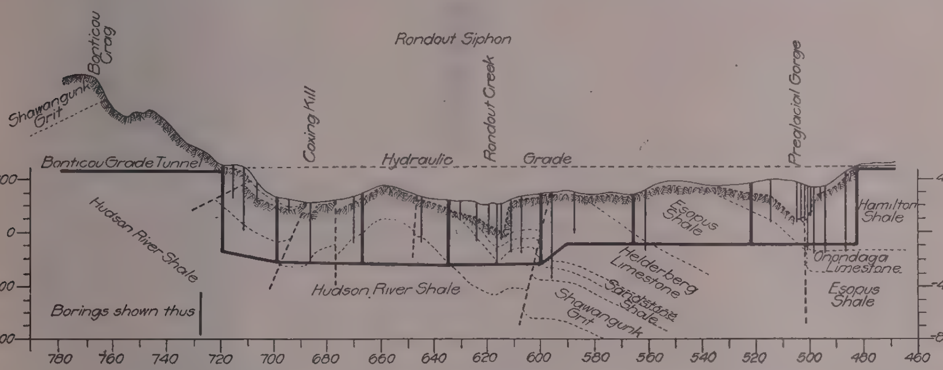
A simple contract suggested by the writer in 1900 was used in the purchase of a low-grade Western coal. This specified the shipping point, route, form of advising of shipment and weights, type of cars to be used, their maximum weight and demurrage regulations. Detailed provision was made as to quantity to be delivered, arrangement of shipments, checking of weights, arbitration regarding weights without delaying the using of the coal, etc. The percentage of moisture was limited to 17½, ash to 14. The method of sampling and analyzing was prescribed. Rejected shipments were to be cared for at the expense of the seller. Coal containing excess percentages of moisture and ash was accepted at the buyer's option at a sliding discount. This contract gave excellent results for about three years. It was not as satisfactory as one based directly on heating value would have been, but was as good as could be made at the time.

The United States Treasury Department has issued a specification and proposal for coal to be supplied to United States public buildings under control of the department. (Form No. 105, March, 1907.) Besides including the general clauses usual in government specifications, the percentages of ash, volatile matter, sulphur and dust (finer than ⅛ in.) are limited. Provision is made for a physical description of the coal desired at various points. Sampling is done by a representative of the government. The methods of the American Chemical Society are adopted in testing for the constituents mentioned above and for moisture. The heating value is determined by a bomb calorimeter. Rejection of coal which in actual service shows excessive clinkering or smoke is provided for. Bidders are required to state the source of the coal, its grade or size, heating value in thermal units and average percentage of ash in dry coal. Payment is made on the offered price as a basis for coal of the heating value specified in the bid. For variations in heating value, the price is changed proportionately. A further correction on a sliding scale is made when the percentage of ash varies. This deduction begins only when the ash percentage is 2 per cent. higher than that agreed upon and ranges from 2 to 35 cents per ton, the latter figure being reached when the excess is over 8 per cent. A maximum limit for ash, of from 12 to 22 per cent., is established. For coal containing less ash than is provided for in the specifications, a premium of 1 cent per ton is paid for each whole per cent. that the ash decreases. The coal is weighed as delivered, and the further correction in payment, based on the variation of ash in dry coal, is made in order to take account of the cost of handling additional fuel and ash, and their effect on the boiler capacity. The whole system of sampling, analyzing and testing is under the supervision of the Fuel Testing Division of the United States Geological Survey.

This should be a satisfactory contract if intelligently applied. There is an evident distrust of the method manifested in the wording of the contract. The provision for rejection on account of smoke and clinkering in operation should be unnecessary if the chemical and physical tests are properly framed and compliance enforced. The general physical description of the coal as required is given more weight than it deserves. According to the specifications "what is desired is not necessarily the cheapest or the highest grade of coal *per se*, but the coal which will insure the greatest net economy in plant operation." This does not seem to be consistent with the further statement that "the heating value expressed in British thermal units ...... is essentially a direct measure of the actual value to the purchaser ......" If the latter statement is true, as the writer thinks it is, then "the highest grade of coal *per se*" is the one "that will insure the greatest net economy in plant operation."

The printed specifications for bituminous coal of the Interborough Rapid Transit Company (New York, 1906-'07,) cover the ground logically and completely. Coal is to be delivered in self-trimming lighters holding not less than 700 tons.

The standard coal must be a good steaming, caking, run-of-mine bituminous coal, free from all dirt and excessive dust, showing, when dry, not over 20 per cent. of volatile matter, 9 per cent. of ash, 1.5 per cent. of sulphur and not less than 14,100 B.t.u. per pound. Sampling is performed by taking a small quantity of coal from each weighing hopper while the lighter is being unloaded. In case of dispute as to the results of tests an outside analyst is employed. If the outside test varies less than 2 per cent. from the company's test (variations being expressed in value of coal) the shipper pays the expense of the analysis, but this second analysis is final and binding on both parties. Heating value is determined by the Atwater-Mahler bomb calorimeter. A sliding scale of premiums and penalties is provided for heating value. The scale ranges from a bonus of 28 cents per ton for coal containing 15,501 B.t.u. or more to a forfeiture of 43 cents for coal ranging below 12,001 B.t.u. Additional deductions are made for excessive volatile matter or ash; these run as high as 18 cents per ton for 24 per cent. of volatile matter, and 23 cents per ton for 13.5 per cent. of ash. Sulphur is penalized up to 20 cents per ton for 2½ per cent. When excessive coal dust is present a deduction of 25 cents per ton is made. Weights are checked by the company's scales, which are made conclusive in case of a difference exceeding 1 per cent. The amount of coal to be delivered each month is specified within 10 per cent. In case of failure to make deliveries the company may buy coal in the open market, any excess cost thereby incurred being paid by the shipper.



Profile of the Rondout Valley and Siphon on the Catskill Aqueduct.

To show that the coal shippers are not wholly averse to selling their product on specifications, reference may be made to a tender made in April, 1907, of 185,000 tons of coal, on specification of size, grade and percentages of ash, sulphur, volatile matter and heating value, with definite (non-exemptive) agreement as to delivery.

Other fuels than coal are used and for other purposes than power production. For smithing a coal low in sulphur and ash and high in volatile matter is necessary. Natural gas, of course, is taken as it comes. Refuse from wood-working establishments is sometimes sold to nearby power plants, being usually delivered by blowing. The quality varies only slightly, excepting as the variable percentage of moisture becomes a factor, though hard wood refuse is less valuable than that from soft wood. In other respects a contract for this material is more like a power contract than one for fuel. Fuel oil should be purchased to specifications. Probably because of the traditions and inertia of the industry, petroleum products are universally sold by bulk. This is an unscientific unit for the power producer, because he is buying fuel value, which is proportional not to bulk, but to weight. Where the price is per unit of bulk, the specific gravity at standard temperature must be specified and the delivered bulk must be at a temperature not exceeding a standard limit. The determination of the bulk should be checked by measurement of the tank cars, reference to the Interstate Commerce Commission's approved table of capacities and observation of discharge into the purchaser's tanks. The percentages of moisture and non-petroleum sediment should be limited as well as that of sulphur. The heating value of oil is extremely uniform; the variation under ordinary conditions with oil from a single field probably not exceeding 2 per cent. A sliding scale of prices, or even a determination of heating value, is often unnecessary.

In recommending the establishing of limiting per centages of sulphur, reference has been intended to power plant operation. For many industrial furnace applications sulphur is less harmful than ash, and its presence is not an objection to the use of the fuel.

To summarize, the purchase of fuel to specification cannot be expected to give rise to any immediate or marked economy, but it encourages a sound and efficient system of plant operation by eliminating one extremely variable factor. The heating value of the coal, as measured in the laboratory, is the prime indication of its value in money; but this should be modified in the light of chemical analysis for sulphur, ash and volatile matter, with consideration of the effect of these constituents on boiler efficiency. Where as elaborate a contract as is suggested cannot be obtained, simple provisions limiting the percentages of moisture and ash, fair stipulations as to deliveries and a more business-like basis for the determination of weights will give beneficial results comparable with those obtained by the more exact system outlined.

The Effect of Superheated Steam on a cast iron valve body recently tested by the Crane Co., Chicago, Ill., was shown by a reduction of strength of 49 per cent., the valve having been in service but a little over four years. A standard 14-in. Crane gate valve was removed from a line carrying superheated steam to be replaced by a steel body valve of similar design, and advantage was taken of the opportunity to determine with accuracy the changes in strength of the iron, the records of the company showing the original tensile strength of the iron from which the valve was made to be 22,400 lb. as determined from test bars. The valve had been placed in service in August, 1903, and was removed in September, 1907, having carried steam during this time at a pressure of 200 lb., superheated ordinarily to about 590° Fahr., but sometimes a little higher. Tensile tests were made of four bars cut from the body of the valve, which showed strengths ranging from 10,610 lb. to 12,440 lb., with an average of 11,740 lb., a loss from its original strength of 49 per cent. Test bars cut from the flanges of the valve, however, showed much less decrease in strength, averaging 33 1/3 per cent., due, it is thought, to the fact that the flanges are not subjected to such high temperatures as is the body of the valve.

The Sub-Surface Investigations on the Catskill Aqueduct, Board of Water Supply, New York City—II.

A paper by Robert Ridgway, Department Engineer, Board of Water Supply, before The Municipal Engineers of the City of New York.

The following descriptions give the leading characteristics of the larger siphons on the Catskill Aqueduct, Northern Aqueduct Department, and of the developments that led to the decision on the type of aqueduct structure to be used for each one.

Rondout Siphon.—The first of the large valleys to be crossed by the aqueduct is that of the Rondout creek, between the Catskill and Shawangunk mountains. The lowest point on the profile of this valley where the aqueduct will cross is the surface of Rondout Creek, some 300 ft. below the hydraulic grade line. A pipe line laid on the surface of the ground would therefore have to resist a pressure of about 130 lb. per square inch, and the steel plates as designed would have to be 1 in. thick at this point. The width of the valley at the crossing is nearly 4½ miles.

On account of the great cost and perishable character of a pipe line, it was decided to cross this valley with a tunnel deep in the bedrock.

From knowledge gained by borings made on a line previously surveyed at Hurley, eight miles northeast of the present line, it was suspected that a deep valley filled with glacial drift existed under the plains on the west side of the Rondout Valley, at Pinebush, although absolutely no evidence of such a bedrock depression is to be seen on the surface. The first borings undertaken were consequently located near the west end of the proposed tunnel, for the purpose of discovering the maximum depth to bedrock in this old gorge.

At Hurley the gorge extended to a depth of 70 ft. below sea level, so that it was expected that a depth nearly as great would be reached at Pinebush. The geologists employed by the board were particularly insistent upon a thorough survey of the bedrock to make certain that no deep and narrow gorge escape discovery. The borings were therefore put down within 100 ft. of each other in the deepest part of the gorge, but the bottom of the old valley on this line extends but a little below an elevation of 100 ft. above tide.

It was first intended simply to locate the surface of the bedrock, by drilling through the glacial drift with heavy casing, and then taking a core with the diamond drill to make sure the bedrock and not a boulder had been encountered. Many of the holes were driven over 250 ft. through glacial drift, while only 25 or 30 ft. of core was taken with the diamond drill.

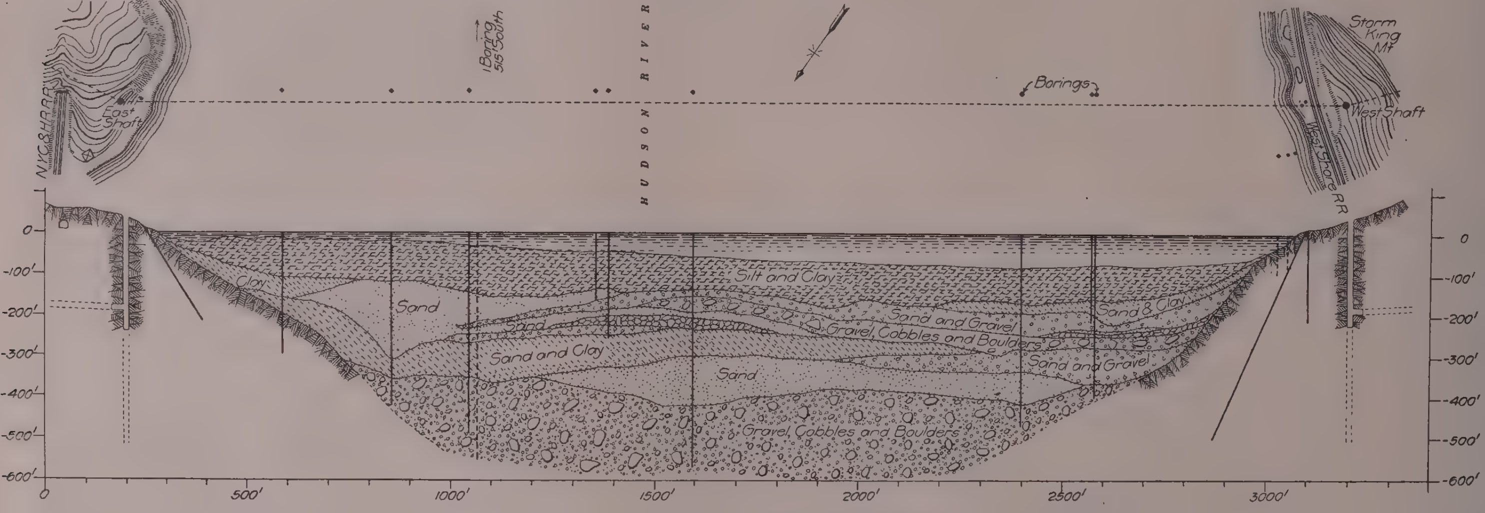
Several of the diamond drill holes, however, extend to a great depth in rock and disclose the interesting fact that a fault with a considerable vertical displacement occurs just under the ancient gorge. The cross-section shows that the bed of Onondaga limestone to the west of the buried gorge lies 130 ft. deeper than the same stratum where it formed the bed of the ancient stream.

These discoveries of the diamond drills show that the tunnel must be kept down very deep at the west end to provide sufficient bedrock cover above the tunnel, so that no danger of leakage of water occurs after the aqueduct is put in service. The grade finally adopted places the tunnel invert at elevation —100, which will cause the tunnel to pass through the fault zone in such a way as probably to avoid the bed of Onondaga limestone.

Still another deep gorge completely filled with glacial drift was discovered under the hill side just west of Rondout Creek. The existence of this gorge was unsuspected even by the geologists. The drills show it to be similar in character to that at Pinebush, worn down along a resistant stratum against softer overlying layers. The west bank of the old gorge was a veritable cliff of limestone, overhanging in places, as shown by one of the drill holes.

From a point near Rondout Creek, all the way to the base of the Shawangunk mountains at the east end of the siphon, the overlying shale and limestone beds have been removed, leaving the very thick and hard layer of white Shawangunk grit which forms the floor of the valley for a distance of 1½ miles. This rock is made up of white quartz pebbles cemented together by silica, and the material is so hard it is used extensively for mill stones for grinding grist and cement rock. Holes drilled through this "millstone rock," as it is termed locally, show its thickness to vary from 250 to 350 ft. Many of the drill holes show the grit to be full of seams carrying water, which flows to the surface. As an obstacle to tunneling, the grit bed is looked upon with considerable distrust, both on account of its hardness, which would make for slow progress and high cost, and on account of its brittle and seamy character and waterbearing qualities.

The great depth of the bedrock gorge at Rondout Creek, with its bottom just at sea level, throws the tunnel deep down into the grit bed. To avoid driving the tunnel for a great distance in this hard and brittle formation, the design adopted places the grade of the tunnel east of Rondout Creek at a depth of 250 ft. below sea level. This will locate the tunnel in the soft and easily excavated Hudson River shales which underly the grit.



Borings Made in the Bed of the Hudson River between Storm King and Breakneck.

At times as many as seven rigs were working in this valley. Most of the borings were made by the firm of Sprague & Henwood, of Scranton, Pa., by rigs which employed a tripod-derrick and hoister for driving the casing, and a diamond drill rig for taking cores after the rock was reached. This method seems to be the most effective of any employed by the contractors on the work in the department. The board has one "steam rig" mounted on wheels, with boiler, pump, winding drum and walking-beam for driving casing. A diamond drill is used in connection with it for drilling in rock. This rig works very well.

Where the surface material is over 200 ft. deep, as at Pinebush and the Rondout gorge, a large size casing is first put down as far as possible, then smaller casing "telescoped" inside the first, and so on until the rock is reached. Sprague & Henwood employ 5, 3 and 2-in. casing, while the board uses 6, 4, 2½ and occasionally 1⅝-in. casing.

Wallkill Siphon.—On the east side of the Shawangunk Mountains the main drainage of the country is discharged through the Wallkill Valley, which will be crossed by the aqueduct in a bedrock tunnel, as in the case of the Rondout siphon. The length of this tunnel will be about 4½ miles, about the same length as the Rondout.

Several lines of borings were made across this valley to explore the ancient bedrock gorge. The first located at Springtown, eight miles north of the present line, showed a wide valley in the bedrock, extending to a depth of 80 ft. below sea level. Other lines farther to the south showed the buried gorge to be much narrower and shallower, until at the crossing finally adopted the bottom of the ancient gorge was found to be at elevation +67. This is the lowest point in the bedrock profile and determines the maximum depth of the tunnel, which will have at this point a rock cover of about 150 ft.

The deep gorge is the most important geological feature controlling the design of this tunnel. Borings were made the full length of the tunnel, 4½ miles to determine the bedrock profile, which is deeply buried in glacial drift, except in a few places. Most of the holes were relatively shallow, extending only a few feet into the bedrock, which everywhere consists of Hudson River shale and sandstone, easy material through which to drive a tunnel, as the rock can be drilled rapidly and will probably carry little water.

Moodna Creek Siphon.—The valley of Moodna Creek, running nearly east and west, is crossed by the aqueduct line near Cornwall. The tunnel will be about 3¾ miles long. The present stream where it is crossed by the center line, about two miles from the Hudson River, has cut down to an elevation of about 120 ft. above tide in the clay and boulder deposit left by the glacier.

Although there is no evidence on the surface, a geological survey and the records of a deep well at Meadowbrook showed the probable existence of a preglacial gorge in the bedrock, deeply filled with drift. It was thought that this gorge probably occurred just north of the present creek, and borings were put down to discover the rock.

A great number of borings in the northwestern half of the line were necessary to develop the floor of this old valley, which lies at an elevation about 50 ft. below sea level. In fact, a double valley with a ridge of rock between was shown to exist. The borings had to penetrate a mass of drift 350 ft. thick overlying the bedrock, and completely filling the old valley for a width of a mile. This is the deepest covering of surface material encountered by the drills anywhere on the line, except in the bed of the Hudson River.

Because of the great depth to bedrock in the Hudson gorge nearby, the geologists insisted strongly that the ancient Moodna Valley be thoroughly explored, that no narrow gorge extending to a great depth below sea level escape notice. Borings were accordingly put within 150 ft. or 200 ft. of each other, but no deep canyon in the level floor of the valley was found.

Borings made along the southeastern half of the Moodna tunnel location, where the bedrock outcrops frequently, discovered two very deep and narrow buried gorges, one near Cornwall, and the other just at the foot of Storm King Mountain. The great depth of these two gorges was a surprise, as their presence is indicated on the surface only by shallow depressions, and without the borings they might easily have escaped notice.

At the northwest end of the siphon, where the vertical shaft for the waterway will be located, the drills show that a depth of about 120 ft. of glacial drift will have to be penetrated. This will require the construction of a reinforced structure above the rock after the manner of a standpipe.

The great depth of glacial drift, over 350 ft. as a maximum, which fills the ancient gorge, would make it a very difficult matter to sink shafts for construction purposes in this long stretch of tunnel, but that the fortunate discovery of the ridge of bedrock between the two buried valleys mentioned will make it possible to excavate a shaft at that point, with only a moderate depth of soft ground to be penetrated.

Drill holes and outcrops show the Hudson River shales to be rock well suited for tunneling. This material resembles the rock at the Wallkill Valley siphon. A short length of the tunnel will be in granite, which is in general very hard. Drill holes in the gully at the southeast end show it to be somewhat decomposed near the surface of the rock, but sound and unaltered in depth.

Hudson River Siphon.—This siphon is the engineering feature of the department which has attracted more attention than any other, and it would be hard to exaggerate its importance. As stated before, the problem cannot be eliminated, as this tidal stream must be crossed by the aqueduct whatever location is adopted. The hydraulic gradient at the crossing is over 400 ft. above the river surface, or nearly twice as high as the floor of the Poughkeepsie Bridge. The column of water of this height represents a hydrostatic pressure of about 175 lb. per square inch.

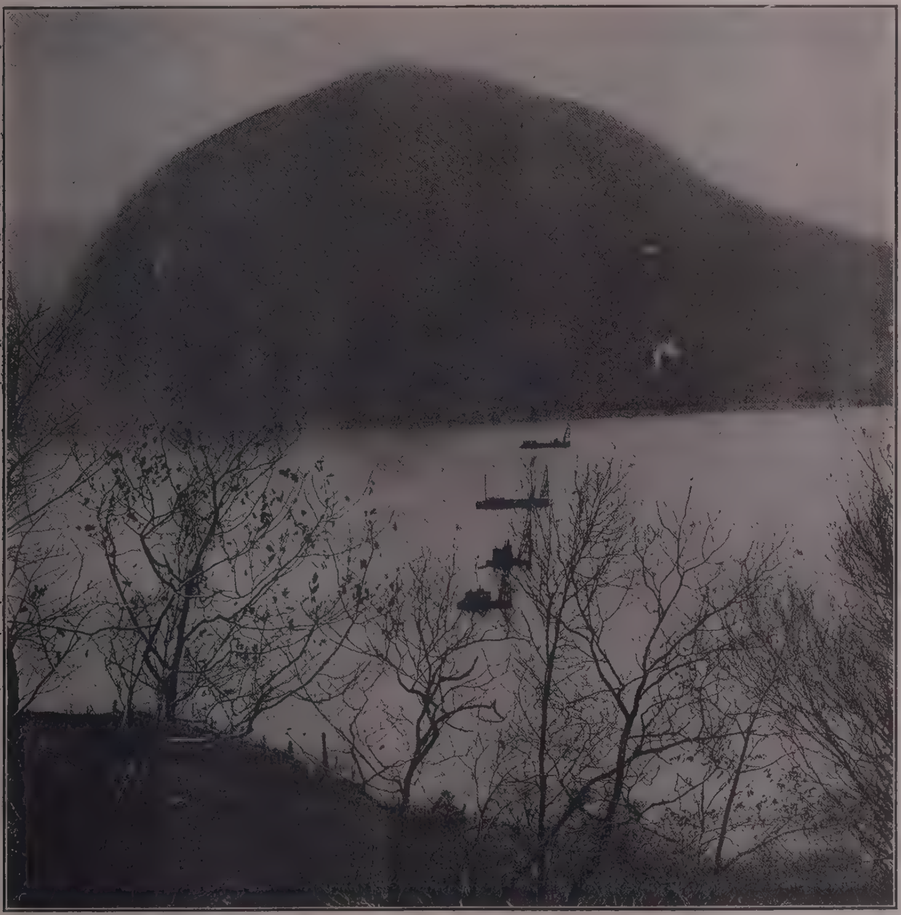
It is possible to carry the aqueduct across the river in a number of ways, among which may be mentioned:

1. A bridge 150 ft. or more above the water surface.
2. Several steel or iron pipes laid in trenches dredged in the river bottom.
3. One or more shield tunnels driven about 100 ft. below the river surface, steel lined or containing one or more steel or iron pipes.
4. A tunnel deep in the sound rock.

Of these the bridge is the most expensive to construct and maintain, and the rock tunnel is the cheapest. As the latter is also considered to be the safest and most durable, efforts have been made to find the most available location for it without eliminating the possibility of using some other form of construction if a thorough investigation should prove it to be impracticable.

In search of such a location every possible crossing has been considered, and the river was studied in the field from Pegg's Point, three miles above New Hamburg, to Anthony's Nose, in the Highlands, a distance of 21 miles. A narrow channel at the point of crossing was desirable, and the geological conditions were an important factor.

It is essential that the tunnel be in sound rock of such a watertight and durable character that no fear need be felt for its safety and permanence. It is needless to point out the disastrous effects of a break in the conduit under the river and the impossibility of repairing it in a short time. Limestone is to be avoided if possible, because of its uncertain character. At any of the upper crossings considered this rock would have to be penetrated either in shaft or tunnel. At and below West Point in the Highlands the presence of limestone of a more doubtful character than that at the upper crossings was suspected with a greater depth of gorge. At Storm King and Little Stony Point granitic gneiss of an excellent quality is found on both shores, with no indication of any change in its character under the river. This fortunate geological condition, taken in connection with the narrowness of the river at Storm King and with the better location leading to this point on both sides of the river, make for decided economy in the cost of construction by that route and lead to the belief that this location is the best one, all things considered. For the past year or more, therefore, work has been concentrated at this crossing.



View of Storm King from Breakneck, with Drilling Rigs at Work.

The explorations are made by means of: First, wash borings; second, core borings; third, test shafts on the shores of the river, from chambers in which diamond drill holes are to be put out under the river. Each method is described in some detail below:

Wash Borings.—At 14 cross-sections of the river lines of borings were made across the stream by means of wash drills operated from the deck of a large lighter. The work was rapid and comparatively inexpensive, but only negative results were obtained, as the wash rods were stopped at depths between 100 and 300 ft. by boulders or hard material. As stated before, this method cannot be relied upon for positive information in work of this character.

Core Borings.—Core borings have been undertaken on only three cross-sections of the river: at Pegg's Point, the most promising one of the New Hamburg routes; at Storm King and at Little Stony Point, about 1¼ miles below Storm King. These borings are much more expensive to make than the wash borings and require far more time. The work in the river has been done under contract by the American Diamond Rock Drill Co. and their subcontractors, the Phœnix Construction & Supply Co., of New York.

At Pegg's Point three holes were successful in reaching ledge at depths of 92 ft., 241 ft. and 165 ft., respectively, and the rock was penetrated far enough to recover good cores and ascertain its character. The river follows a fault at that point. One of the holes was east of it, in limestone similar to that being quarried at Clinton Point on the east shore. Two holes were west of it in Hudson River shale. The deepest part of the gorge is probably on the fault line and was not explored, as by the time the borings mentioned were completed it was decided for a number of reasons to investigate the Highland crossings. At Little Stony Point no boring was carried to rock.

In September, 1906, the first core boring was begun on the Storm King line, and the work has been carried on there since, except during the winter months, when the ice in the river prevents any work of the kind from being done. Of ten borings begun on this line, only two have thus far been successful in getting down to the rock. Five were left unfinished at the close of the last working season, and three were lost through the action of the elements. When the ice begins to form in the river the work is suspended for the winter and the casing pipes uncoupled below the navigation depth. When the river opens in the spring the casings are connected up again and the work resumed. The positions of the holes are, of course, carefully located, and the submerged pipes can be found without much difficulty. To carry on the work in the winter is out of the question, as the floating ice moving back and forth with the tide would carry away the scows, and the casings and the holes would be lost. It is not safe to attempt to work from the ice when the river is frozen tight. Even if the ice became strong enough at any time to carry the weight of the apparatus, a sudden thaw would cause it to break up suddenly and result in the loss of the rigs and perhaps the men. All of the work, therefore, must be done from floating platforms. The methods are thus described by Mr. Walter T. McIntosh, the assistant engineer who acted as the inspector of the work last season.

"The equipment used on the river borings consisted of scows equipped with pile-driving apparatus and duplex pumps of different makes and sizes. The outfit giving the best satisfaction was a scow 35 x 100 ft., with 60-ft. pile-ways and equipped with a 40-h.p. Lambert hoisting engine, with Lambert boiler and Blake duplex pump delivering about 100 gal. per minute at 120 lb. pressure. The scows were held in place by means of from six to ten mushroom anchors, weighing in the neighborhood of 1,000 lb. each and having from 200 to 400 ft. of lead, according to the depth of water. Most of the anchor lines were ⅞-in. wire elevator cables, second hand, though ½-in. iron chains and 2-in. manila lines were also used.

"The sizes of casing used were 14, 12, 10, 8, 6 and 4-in. casing, and 2½-in. extra heavy drive pipe. Only two holes were started with 14-in. casing, the others being started with 8 or 10 in. The method of driving casing was to wash down with a 2-in. stream of water and drive the casing as close as possible after the wash pipe. It occasionally became necessary to bail out the casing with a sand pump when working in sand and gravel.

"When boulders were encountered it usually became necessary to blast them out of the way. Sixty per cent. dynamite was used in this work, and shots consisted of from four to twenty sticks. When they were set off the casing was pulled back from 10 to 20 ft. At a depth of 473 ft., in one of the holes, a nest of boulders occurred which required six shots, aggregating sixty-six sticks of powder, to make it possible to drive the casing 2 ft. It was found, in general, that the first size of casing could be driven 100 ft. below the river bottom and each of the other sizes 100 ft. or more below the last preceding size.

"When the casing brought up against something solid, that blasting would not remove, a platform was erected on the casing and the diamond drill set up. For this work an American Diamond drill was employed, using 1⅝-in. rods and recovering 1⅛-in. core.

"The force on each barge consisted of a diamond setter and three or four helpers, depending on the size of casing handled. A superintendent on the ground had charge of all the work."

In the early stages of the work the platform for the diamond drill, instead of being atached to the casing, was supported by a tower formed of four piles driven into the river bottom. The bottom of the tower was about 25 ft., and the top 15 ft. square, the tops of the piles being drawn together and held by tie rods. It was found in practice, however, that the telescoped casing is stiff enough for the purpose, and the towers were given up as expensive and cumbersome. Of the two borings at Storm King which have reached rock, one, No. 16, 300 ft. from the east shore, encountered it at a depth of 201.4 ft. below the river surface, and the other, No. 10, nearly 800 ft. from the shore, at a depth of 608.6 ft. The latter hole was begun on Sept. 10, 1906. Operations on it were stopped for the winter in December, 1906, and were resumed in April, 1907. Although work was prosecuted earnestly on it thereafter, it was not until the latter part of August of that year that the casing was seated in the rock and drilling begun. The diamond bit had gone 9 ft. into the rock and was making good progress, on the night of Aug. 30, when the steamboat "Poughkeepsie," having broken her propeller, drifted down against the casing, bending the latter and wrecking the platform. Investigation showed that the bends were below the river bottom and that straightening the casings was out of the question. The hole was therefore abandoned one year and a day after it was started. Although only 9 ft. was bored into the rock, it is believed that the latter was ledge and not a boulder, especially as the core is of the same character as the rock on the mainland. This hole reached the greatest depth attained thus far in the river work.

At the close of the past season one of the five unfinished borings was down 580 ft., this depth having been reached in 4½ months.

The work of making these river borings has been most difficult. It is not believed that such work has been attempted before under anything like the same conditions. Here the depths to be drilled are unknown, and the problem is entirely different from one where a fixed grade only is to be reached.

The channel at Storm King reaches a maximum depth of 85 ft., not far from the west shore. Underlying the channel is silt and clay, then sand and gravel of increasing coarseness and boulders. Depths from 300 ft. to 400 ft. can be reached with comparative ease, and after the rock is reached the drilling does not present very unusual difficulties. The troubles occur in the bed of gravel and boulders, where sometimes weeks are spent without the gain of a foot. Much trouble was experienced with the dynamite, which often would not explode at great depths, due to the pressure and the low temperature of the water. A failure to explode in such cases means much loss of time and generally of footage. Sometimes two lines of casing became bound together by gravel lodging between them, preventing the smaller size being driven without carrying the larger with it. It should be remembered that every size of casing extends from several feet above the river surface to the depth to which it is driven. Serious troubles have also been caused by storms, the river in the contracted channel at Storm King being very rough at times. The anchors have dragged on a number of occasions, and this has resulted in the loss of three holes on that line.

Test Shafts.—As it is not practicable to make enough core borings in the river to locate a possible fault or a narrow crevice in the bottom of the gorge, and as the encountering of a water-bearing seam by the tunnel at such a depth might mean the loss of the heading, it was decided to sink two shafts, one on each shore, to a depth of 650 ft. below tide, and from chambers excavated in their sides put out horizontal or inclined diamond drill holes that would cross under the middle of the river and furnish evidence of the character of the rock all the way across. As the shafts are to form part of the permanent construction, they were located and designed accordingly. Work was begun on them early in 1907, under agreement with the Cranford Co., of Brooklyn, and to date each has been sunk approximately 250 ft. At elevation —185 headings were turned for the aqueduct on the land sides and were driven about 25 ft., so that they can conveniently be extended later. Below this elevation the shafts are circular in section, as they are to form the aqueduct waterway.

Excellent rock has been encountered all the way down of the same general character as the outcrops. The shafts have been remarkably dry. About 5 gal. of water per minute only has to be removed from the east shaft and is easily taken care of by bailing. In the west shaft the quantity to be handled is about 12 gal. per minute, but sometimes reaches 18 gal. after a storm, most of it coming from the surface.

In conclusion, the writer desires to record his indebtedness to the engineers of the Northern Aqueduct Department, who have assisted him in writing this paper, particularly to Assistant Engineer James F. Sanborn, who has prepared for him the detailed descriptions of most of the siphons.

Appendix 17, Report of Royal Commission on Quebec Bridge Failure.

A comparison of the design for certain chords of the Quebec Bridge with those for similar members of other great cantilever bridges.

The outlines of six great cantilever bridges are shown on Drawings 31 and 32 [not reproduced], and detail plans of the lower chord construction adopted for each bridge, on Drawings 34, 35 and 36 [not reproduced]. The position of the chord selected is shown in each case on the outline drawings, except for the Forth Bridge; the detail drawing for this bridge is simply a sketch plan showing the general make-up of the main compression members.

In the attached table we introduce for use in comparison, an example giving the dimensions of an ordinary bridge post of the two channel type, the figures being taken from Professor Burr's "Elasticity and Resistance of the Materials of Engineering." These dimensions are more or less typical of those latticed columns that have been used in bridge construction with such success during the last twenty-five years; the details of such columns are now designed entirely by practical rules.

Table of Chord Details Prepared from Drawings 34, 35 and 36, Report of Royal Commission on Quebec Bridge Failure.

Bridge.	Area of cross section.	Area of latticing in a section (measured at right angles to lattice axis).	Area of rivets connecting lattices cut by section to outside web (one end only).	Length of chord = l.	r in plane parallel to latticing.	$l \div r$	Weight of plain section per lin. ft.	Weight of latticing per lin. ft. of chord.	Depth of chord back to back of web angles.	Width of chord out to out of web plates.	Section of horizontal splice plates.	Section of vertical splice plates.
	sq. in.	sq. in.	sq. in.	ft. in.	in.		lb.	lb.	ft. in.	ft. in.	sq. in.	sq. in.
Quebec	781	10	4.8	57 0 9/32	19.7	35	2603	66	4 6½	4 9⅜	68	212
Memphis	213	10	4.8	28 2¾	14.8	23	710	48	2 6¼	3 2	46	230
Blackwell's Island	852	25	4.8	31 6⅛	22.	17	2840	144	4 0½	5 2⅝	80	187
Thebes	189	11¼	4.8	30 6 5/32	20.1	18	630	78	3 0½	4 4¾	80	70
Monongahela	262	14½	7.2	30 6 1/32	25.4	14	873	82	3 0¾	4 1	74	164
"Burr"	35	3¾	1.2	45 0	6.5	83	118	20	1 6	1 0¾	—	—

Note.—The horizontal stiffness of the inside ribs of the Quebec Bridge chords is less than that of the outside ribs, which is not the case in any of the chords of the other bridges. (See also table in Appendix No. 18.)

It will be noted that the Forth Bridge chord is in a class by itself. It is not a latticed section, but may be regarded as a solid section built up out of separate plates. No criticism touching the practical success of this design has ever been made, but it is not a class of construction that could be adopted by an American bridge company without making material changes in its shop equipment and methods of handling its business. We have, however, noted in Appendix No. 18 that the work of the Forth Bridge designers is worthy of careful study.

The examples taken from American practice may be divided into three groups:

(1) Chords of the ordinary two channel type which reaches its maximum development in the Monongahela design.

(2) Chords of the four channel type latticed into one column as adopted for the Memphis and Quebec bridges.

(3) Chords of the four channel type latticed into two columns, which are made to act together by means of tie-plate connections.

This type was adopted for the Thebes and Blackwell's Island bridges.

In the accompanying table we give the principal dimensions of the chords shown on the drawings.

It is almost impossible to find any common basis for a comparison of these chords. It must be remembered that latticing is often uniform in size in members on the same bridge doing similar service, but having different loads and cross-sections. Thus in the Quebec Bridge A9L had an area of 781 sq. in. and A1L an area of 301 sq. in., yet both members had about the same outside dimensions in cross-section and the same latticing. Therefore as the chords selected for the drawings are not the most heavily stressed chords in the respective bridges, comparison by proportion of lattice to main sections would be unfair. In fact we may say that the drawings given are only typical.

A theoretical comparison between the lattice systems of the different columns might be made by using any one of the various formulas given in Appendix 16, but we have already pointed out that no one of these formulas is generally accepted by the profession. There are so many causes of variation in the strength of built-up chords of equal area which are not provided for in these formulas, that comparison by calculation does not appear to be satisfactory.

Referring to the table, it will be noted that the Quebec chord has considerably less horizontal stiffness (see values of l/r), less lattice area, less rivet area, and less splice plate area in proportion to the size of the members than any of the earlier bridges. It should be remembered, also, that the unit stresses for the Quebec Bridge were higher than those of the earlier bridges. It will be noted that the earlier designers considerably overran the 15 or 20 per cent. of splice plate area. This is also true of the Quebec Bridge chords, but not to the same extent. Mr. Szlapka states that splice plates having an area of cross section equal to 15 per cent. or 20 per cent. of the cross section of the member would be satisfactory.

The development of the detail plans of the Blackwell's Island Bridge was contemporaneous with that of the Quebec Bridge plans; the Quebec designers had not access to the Blackwell's Island plans. In fairness to the Quebec Bridge designers, however, it should be pointed out that in the Blackwell's Island Bridge the proportions of many of the details are much more nearly in accord with the Quebec Bridge practice than are those of the earlier bridges, although the principles of the designs are very different.

A consideration of the difference in the designs on Drawings 34, 35 and 36, all of which have been prepared under the direction of engineers of recognized ability and high professional standing, shows that there is as yet no established system of design for large compression members. The individual judgment of the engineer is the determining factor and this may prove to be erroneous, as it did in the case of the Quebec Bridge.

The lack of precise knowledge on this subject has been discussed in other appendices.

(Signed) Henry Holgate,
Chairman.
J. G. G. Kerry.
J. Galbraith.

Appendix 18, Report of Royal Commission on Quebec Bridge Failure.

A critical discussion of certain parts of the specifications.

The Quebec Bridge was designed to meet the requirements of the specifications approved by the Dominion Government in 1898 and amended in 1903. The method adopted by the company to procure tenders was to issue a general specification and to call upon contractors to prepare plans in accordance therewith.

Considering all the conditions pertaining to the undertaking, the adoption of this method was not in the best interests of the work. The company was known not to have the capital necessary to proceed immediately with construction, and the preparation of complete preliminary plans would involve a large outlay. The evidence and documents show that the preliminary plans submitted with the tenders were incomplete; this was as might have been expected, as the several contractors who tendered for the work had little assurance that they would get any return for their expenditure of time and money.

Specifications as a rule consist of two distinct portions, one of which relates to design and the other to fabrication, material and execution. In the case of the Quebec Bridge, the difficulty of preparing an adequate specification for design was very great. It would have been better to have entrusted the preparation of the plans and specifications to engineers independent of any contracting or manufacturing company, whose previous experience qualified them to handle the work. This course would have avoided duplication of designs involving expensive plans, and would have prevented the letting of a contract on incomplete plans formed upon erroneous data; the engineers would have made a proper and sufficient study of the whole project, and in due time competitive tenders upon their plans would have been secured, thus enabling all contractors to tender on a common basis. The privilege of submitting independent plans might have been extended to the bidders. The reason for not following this course is explained by Mr. Hoare in his evidence.

The procedure as outlined above would have been applicable to an enterprise which involved so many new problems and the application of existing knowledge on so large a scale and which demanded the continual exercise of sound judgment.

An error of judgment made by the Quebec Bridge Company was the selecting of an engineer who did not possess the necessary special knowledge and experience to prepare the specification. (See Appendix 7, Engineering Record, March 14.) It is true that this specification was considered to be only tentative, drawn up for the purpose of procuring preliminary tenders, but its history and importance cannot be overlooked. (See Appendix 6, Engineering Record, March 14.) It became the basis of the contracts between the Quebec Bridge Co. and its contractors, was approved by the Government engineers, and was an essential part of the subsidy agreement whereby the Dominion Government undertook to pay the Quebec Bridge Co. on certain conditions one million dollars.

The specification itself, herein called the 1898 specification, was for the most part a copy of a specification issued by the Department of Railways and Canals in 1896; there is nothing in its wording to indicate that the Quebec Bridge was an exceptional structure and without precedent or that the propriety of applying to this structure other than the usual clauses in bridge specifications was carefully considered.

We do not think that any engineer would be justified in writing a specification without consulting freely those specifications most used in practice; specifications are, in fact, the statement of the provisions that engineers have in the past been forced to make in order to secure satisfactory results, and each succeeding revision is the outcome of experience. Such compilations are necessary and cannot be dispensed with, but this fact does not justify an engineer, whose special experience has not fitted him to judge of the importance of vital clauses, in revising and rearranging them. The danger in so doing lies in the fact that a clause necessary and useful in one specification may not be applicable under other conditions, and opinions on such matters are valuable only from men of special qualifications. Errors arising from the compilation of specifications by experienced men are by no means uncommon. Mr. Cooper recognized this and so revised the specifications of 1898.

In regular bridge practice the specification is of importance particularly because an American bridge works is a factory for turning out structural steel fabricated in accordance with plans prepared in the drawing office attached to the works. This drawing office is a part of the factory, and in it, as throughout, efficiency is obtained by standardizing and duplication; the drawing office staff consists of a number of well-trained computers and draughtsmen whose duty it is to prepare the shop drawings for the work and who are under the control and direction of a designing engineer. Details are designed in accordance with the specifications furnished by the purchaser, except under circumstances when shop equipment requires some deviation to be made to secure facility of manufacture. It is not a part of the duty of the drawing-office staff to question the wisdom of the requirements of the specification nor could the progress of work throughout the factory be satisfactorily maintained if it should attempt to do so.

The evidence shows that the Phœnix Bridge Co. followed this usual practice in the preparation of the Quebec Bridge designs.

In 1903 it became necessary to design the main spans of the bridge and the 1898 specification was amended by Mr. Cooper, it having been understood ever since 1900 that it would be amended and altered. The history relating to the adoption of these amendments is given in Appendix 4.

Mr. Cooper did not recognize these amendments as complete and final, and considered that he had the power to deal with each problem of design as it arose, and he exercised this power when he thought it necessary. The designing of the main span was left to Mr. Szlapka, Mr. Cooper having approved the specifications, and no one questioned any decision that these engineers made. The work was done under the immediate direction of Mr. Szlapka.

Before discussing the specification, it will be well to contrast some of the main features of the Quebec Bridge with those of other cantilever bridges and the accompanying table is inserted for this purpose.

It is not possible to set forth all the facts in a table with sufficient minuteness to justify the making of complete comparisons as many qualifying clauses and special conditions are necessarily omitted. Three items of interest may be noted in the table:

(1) Only the Forth Bridge is at all comparable with the Quebec Bridge in regard to span.

(2) Only the Blackwell's Island Bridge is comparable with the Quebec Bridge in regard to unit stresses both for main members and for details.

(3) All the bridges included in the table were designed by independent engineers except the Quebec Bridge.

In this connection we must express the opinion that it is difficult for the employees of a large manufacturing concern to give the design of a bridge of unique features the concentrated attention that it requires.

With regard to precedent, only the Forth and Blackwell's Island bridges involved anything like the same total stresses as the Quebec Bridge. The design and construction of the Blackwell's Island Bridge was contemporaneous with the Quebec Bridge.

Information Concerning Great Cantilever Bridges.

Name	Date of Construction.	Designer	Contractor for Superstructure.	Span. Ft.	Width C. to C. Trusses, Ft.	Live Load per Lin. Ft. Lb.	Ultimate Tensile Strength for Steel. Unit 1,000 Lb.	Approx. Weight of Steel in Short Tons per Lin. Ft.	Price for Structural Steel per Lb., Cents.	Working Stresses Lb. per Sq. In.	Allowed Shear on Rivets. Lb. per Sq. In.
Forth	1882-1889	Baker & Fowler	Wm. Arrol & Co.	1,710	varying lower chord 31½ at ends to 120 at piers.	Double track Ry., 2,240 lb. per track.	Compression 76-83 Tension 67-74	10½	6.50	Max. stresses Compression, 17,000 Tension, 16,350.	about 12,000
Memphis	1886-1892	Geo. S. Morison	Union Bridge Co.	790	30′	Single track Ry., 4,000 lb. per track.	Compression 69-78½ Tension 66-75	3½	5.88	Compression 14,000 if l is less than $16d$; deduct 750 lb. for each additional unit over 16 in $l \div d$; tension for dead load 20,000; tension, live load 10,000.	7,500
Monongahela	1902-1903	Boller & Hodge	American Bdg. Co.	812	32′	Double track Ry., 4,500 lb. per track.	Compression 60-70 Tension 63-75	4½	4.3	Compression; dead load, 21,000 where l/r is less than 40. Tension, dead load, 22,000. Take one-half in each case for live load.	10,000
Thebes	1902-1905	Noble & Modjeski	American Bdg. Co.	671	32′	Double track Ry., 5,000 lb. per track, less 20 per cent.	62-72	5	5¼ (not official)	Compression dead load 21,000 if l/d is less than 16. Tension 20,000. Take one-half in each case for live load.	7,500
Blackwell's Island	1901-1908	Dept. Bridges New York City	Pennsylvania Steel Co.	1,182	60′	Roadway and trolley; ordinary, 8,000 lb., congested, 16,000 lb.	Compression 60 ÷ 4; Tension 66 ÷ 4; Nickel Steel eyebars 85.	13½	5⅝ (not official)	Compression ordinary 20,000—l/r; congested 24,000—100 l/r. Tens'n ord'y 20,000; congested 24,000. Tension for nickel steel ord'y 30,000; cong'd 39,000.	ordinary 13,000 congested 16,000
Quebec	1900	Phœnix Bridge Co.	Phœnix Bridge Co.	1,800	67′	Double track Ry., Roadway & Trolley; 4,000 lb. per track. For extreme conditions mult. 1½.	Compression 60-70 Tension 62-70	13	5.60	Compression ordinary 12,000 (l + Min./Max.) Extreme 24,000 both for l/r less than 50. Tension ordinary 12,000 (l+Min./Max.). Extreme 24,000.	¾ working stress = 18,000 extreme.

The Forth Bridge was built on a system not suited to the established American methods of bridge construction, so that its distinctive features of design, construction and erection were not followed. It is proper to add that the achievements of the Forth Bridge engineers deserve much closer study than appears to have been given to them on this continent. Messrs. Baker & Fowler succeeded in erecting a structure which weighs considerably less per lineal foot than the Quebec Bridge and which is designed to carry about one-half the rolling load and several times the wind load specified for the Quebec Bridge. The main compression chords of the two bridges are of practically equal area but the material in the Forth Bridge is of a considerably higher ultimate strength than that used in the Quebec Bridge, the unit stresses are less and the design of the cross section of the chords is such that they should be able to carry a greater unit stress with safety. On great bridges these are factors to be observed, and it is to be regretted that the stress sheets and full engineering studies in connection with the Forth Bridge have not been published.

It is evident that the designers of the Quebec Bridge were compelled to work from experience gained on much smaller bridges.

In discussing the specification we deal not only with the clauses immediately connected with the downfall, but with others that were not, in our judgment, calculated to ensure a safe and satisfactory structure.

The specification is here understood to mean the 1898 specification as amended in writing by Mr. Cooper.

As a document the specification is unsatisfactory, some of the clauses having been amended by Mr. Cooper, some set aside in favor of his well known and generally accepted standard specification, and some remaining in force with a context that altered their meaning. No general or complete revision of the specification embodying Mr. Cooper's amendments was ever compiled.

As a matter of fact, although the 1898 specification was retained as the official specification and much of the work done in accordance with it, we believe that Mr. Cooper depended upon his own inspection of the plans under the revised specifications to secure satisfactory details. His opinions upon most debatable questions of design were well known to the staff of the Phœnix Bridge Co., which had previously designed and built many structures under his direction and was accustomed to his methods. It is on record that the Phœnix Bridge Co. requested Mr. Cooper to set aside the 1898 specifications altogether and to substitute for them his own standard specifications.

A complete bridge specification must set forth the character of the material that is to be used, the loadings that are to be carried, the stresses to be permitted in the members and provisions concerning details, fabrication and erection to be observed; in fact everything essential to the proper carrying out of the work as intended.

The 1898 specification for material was used without alteration except in one particular, Mr. Cooper having raised the minimum limit for the ultimate strength of eye-bar material from 60,000 to 62,000 lb. The metal specified was the ordinary grade of structural steel.

It will be noted by reference to the table that the Quebec Bridge specification called for material of slightly lower ultimate strength than that used in any of the other bridges, while the bridge itself had the longest span of all. The need of a better material than structural steel for the construction of long-span bridges is generally recognized, because the decrease of total weight and consequently of cost in a large truss with increase of permissible unit stress is very rapid. In the Quebec Bridge the dead load stresses constituted, roughly, two-thirds of the stress on the main members.

The designers of the other two great bridges introduced special grades of steel so that high unit stresses could be safely used. The Forth Bridge engineers were not permitted to load their metal to more than one-fourth of its tensile strength, and for compression used a steel about 25 per cent. stronger than that supplied for Quebec. Nickel steel with a permissible unit stress 50 per cent. higher than allowed on material in the same bridge and similar to that used at Quebec was introduced into bridge practice by the Blackwell's Island Bridge designers. The use of this alloy as a structural material was investigated and favorably reported upon in 1903 by a special commission of which Mr. Cooper was a member.

It was Mr. Cooper's opinion that it was wiser to use the ordinary grade of metal for the Quebec Bridge and to load it to the highest working stresses that were considered practically safe.

Elastic Limit.—We do not know whether Mr. Cooper in his amendments intended the term "elastic limit" to mean the elastic limit of a test specimen or of a full-size member. There is also some uncertainty as to the true meaning of the term "elastic limit," which is unfortunate, as the maximum working stresses specified are made to depend upon this characteristic of the material.

The "elastic limit" accepted by bridge designers as a controlling factor in their work cannot be determined by the method prescribed by the 1898 specification, and yet this method (the drop of the beam) was used. Both Mr. Cooper in his standard specifications and the engineers for the Blackwell's Island Bridge provide for a much closer determination of this characteristic. In reality the determination is a delicate and time-consuming process for a research laboratory and impossible under the conditions existing in a rolling mill; to such an extent is this true that it is not called for in the carefully prepared specification issued by the American Railway Engineering and Maintenance of Way Association in 1906. The principle apparently followed in the latter specification is that mill tests are sufficient for mill purposes and that the true elastic limit can be most safely obtained by proportion from the ultimate strength. The assumption generally made is that the true elastic limit for structural steel is about 50 per cent. of the ultimate strength.

The material actually supplied for the bridge was regularly tested and a comparison between its probable elastic limit and the 32,000 lb. per square inch apparently expected by Mr. Cooper, is possible. The full-size eye-bar tests show that the metal in service shape had a safe ultimate strength not in excess of 55,000 lb. per square inch and a reported elastic limit of 28,000 lb. per square inch. These tests were made on long bars in the Phœnix Iron Co.'s large testing machine and the results might be reduced by calibration of the machine and closer observation of the elastic limit. It will be noticed that the proposed extreme working stresses (24,000 lb. per square inch) for the Quebec Bridge were nearly equal to the elastic limit of the eye-bars.

The elastic limit in compression was assumed in accordance with the usual practice to be the same as that in tension. An examination of the voluminous test records shows that an ultimate strength in excess of 60,000 lb. per square inch was not regularly secured, so that, accepting the 50 per cent. relation mentioned above, the elastic limit in compression becomes 30,000 lb. per square inch. It should be noted that these tests were made on specimens of about ½ square inch sectional areas. The compression members were built up of wide thin plates riveted together into webs. We know of no test that has ever been made to establish the relation between the strength and elastic limit of such plates and those of small test specimens, nor do we know what effect the punching, riveting and painting have on the material in the webs as compared with the solid plate. It was noted at the wreck that the paint between the plates of members that had been fabricated for over three years was still fluid. From the analysis of full-size tension tests we think it possible that the elastic limit of the plates in the compression members was not much above 27,000 lb. per square inch, instead of 32,000 lb., as apparently assumed.

Unit Stresses.—The maximum unit stresses that Mr. Cooper proposed to use were about 21,000 lb. per square inch under ordinary loading and 24,000 lb. per square inch under extreme conditions. He considered that the extreme conditions as specified would never occur.

By reference to the table it will be seen that the specified stresses for the Quebec Bridge under working conditions are in advance of current practice, and we believe that they are without precedent in the history of bridge engineering. Under extreme conditions the Quebec Bridge stresses are in general harmony with those permitted in the Blackwell's Island Bridge.

We have already indicated that the dimensions of the Quebec Bridge were such that the use of the highest safe unit stresses was justifiable and good engineering practice. If we were sure that the loads were correctly estimated, that the stresses acted in the bridge exactly in accordance with the assumptions, and that the elastic limit of the built-up members was not less than 32,000 lb. per square inch, 24,000 lb. per square inch would not be an unsafe stress for structural steel, provided that the material is regular in quality and the details satisfactorily worked out to suit such a stress.

Mr. Cooper provided for the effect of live load by the use of the so-called fatigue or (min./max.) formula. This method, which was formerly much used, has more recently been abandoned in general practice and is not adopted by Mr. Cooper in his standard specifications. In the hands of an experienced engineer this method will be made to produce much the same results as the more modern impact formulas. We do not know why this formula was used in this case, except that it was adopted by Mr. Hoare in 1898 from the 1896 specifications of the Department of Railways and Canals and was probably retained in 1903 for convenience.

Mr. Cooper adopted the ordinary straight line formula for compression members, making the dead load unit stress equal to $(24{,}000 - 100\ l/r)$ lb. per square inch. We have already indicated in Appendix 13 (Engineering Record, April 11) that this formula is purely empirical and does not agree particularly well with the recorded tests upon large columns. It is the most generally accepted formula of practice, but we do not believe that the engineering profession has at present a satisfactory knowledge of the action of large steel columns.

There is a wide field for experiment which must be worked over before engineers can claim to have a sufficient knowledge of steel to design both safely and economically, and perhaps the most serious criticism of the structural engineers of the present day is that they have permitted this field to remain undeveloped for twenty-five years, during which time they have adopted a new metal for their work and new shapes and sections.

We think that in popular engineering opinion, the ultimate strength of steel columns is largely overestimated, the diagram on Drawing 20 (Engineering Record, April 11) indicating that for the Quebec chords it was not safe to expect an ultimate strength in excess of 32,000 lb. per square inch, so that under the extreme conditions specified the margin of safety would only have been one-third.

This is a point on which current engineering practice is open to direct criticism. The older engineers, upon the results of whose experiments the profession is now depending, did not think of loading metal in compression to the unit stress used in tension, because they recognized that the ultimate unit strength of members in compression was far less than that of members in tension.

The later school of engineers seems to have adopted the principle that the action of bridge members under stresses in excess of the elastic limit is a matter of indifference, as they will never be so stressed. The action within the elastic limit being practically the same under both conditions, they adopt the same working stresses in tension and in compression. Their practice has been attended with complete success, but this may be attributed to the fact that the material has ordinarily not been stressed to much above half the elastic limit.

Under the Quebec Bridge conditions, where high working stresses were imperative, the wisdom of the practice of loading in compression as heavily as in tension becomes questionable. We believe that in no great public structure should stresses be permitted in excess of one-half of the ultimate strength of any compression member, no matter how high the elastic limit may be.

It will be noted that Mr. Cooper, in specifying the stresses for the lower chords of the Quebec Bridge, omitted the term in the column formula containing the ratio l/r. In this practice he is supported by the engineers of the Monongahela and Thebes bridges, who made a similar provision, but reduced the maximum stress to that allowed by the usual formula for a column with l/r equal to about 40.

The failure of the Quebec chords does not prove that Mr. Cooper was theoretically incorrect and cannot be directly connected with this clause in the specification. The specification, however, permitted stresses in advance of any previous practice, and the proportioning of columns to safely carry such stresses is yet to be learned.

We have already pointed out the seriousness of the error made in the estimation of the dead load, which resulted in computed stresses nearly 10 per cent. higher than had been expected. A comparison of these computed stresses with the elastic limit of the material as estimated from the test records will show how narrow a margin of safety was provided in the actual design.

We are not prepared, in the present status of the art of bridge building, to approve the unit stresses stated in the amended specification.

Rivet Stresses.—It will be noted from the table that the rivet stresses used were much in excess of previous practice. These seem to have been adopted almost by an oversight. The 1898 specification contained a clause usual in low-stress specifications, permitting the rivets to be worked to three-quarters of the allowed stress in the member. This clause was not canceled by the 1903 amendments and under extreme conditions permitted a stress in rivet shear of 18,000 lb. per square inch. The tests made in 1904 under the direction of the American Railway Engineering and Maintenance of Way Association have established the fact that a riveted connection begins to work under a stress in rivet shear between 12,000 and 15,000 lb. per square inch and that deformation in even a simple connection is marked when a stress of 25,000 lb. per square inch is reached. These results have been confirmed both in tension and compression by the tests made for the Commissioners (see Appendix 15, Engineering Record, April 18). It is therefore clear that the Quebec specification permitted the use of stresses in details which were outside the limits of established practice and are now known to be unsafe. Knowledge of the action of the rivets in riveted connections is very incomplete.

Built-Up Columns.—In our findings we have stated that the bridge failed through weakness of the lower chords and particularly in the latticing of those chords. In Appendix 16 (Engineering Record, April 18) will be found a discussion of lattice design and of the data that Mr. Szlapka had to guide him in his work. The main outline of the latticing in the Quebec Bridge was sketched as early as 1898. There was practically nothing in the specification that was of any service to the designers in this connection and they violated none of its provisions in the design. There are some clauses dealing with latticing, but they were copied from small bridge practice and were wholly inadequate for the Quebec structure. The main criticism that can be made of the designers was that they had the means of checking their theories by the use of the testing machine and that they did not do this nor did they thoroughly study the possibilities of lattice formulas.

Loadings.—In 1903 Mr. Cooper revised the loadings, increasing the specified train loads and decreasing the wind pressures. While Mr. Cooper undoubtedly made an improvement on the 1898 specification in this respect, he does not seem to have taken full advantage of the improved financial situation due to the decision of the Government to guarantee the Quebec Bridge Company's securities. This is explained by Mr. Cooper in his evidence, in which there is no reference to the changed financial conditions. (See Appendix No. 5, Eng. Record, March 14.) Mr. Cooper apparently did not realize the great change in the traffic conditions that would probably follow the opening of the National Transcontinental Railway nor the demands for transportation resulting from the rapid development of Canada. His specified train loading is not greater than that used regularly in Canadian practice and is lighter than that subsequently adopted for the National Transcontinental Railway, and sufficient provision was not made for probable increases of live load.

Considering together the high unit stresses permitted and the loads specified, the specification was not for a bridge well suited to the purposes it would have been called upon to serve.

Dead Load.—The specification requires that the dead load used for calculating the stresses shall not be less than the actual weight of the structure when completed. The evidence shows that the designers failed to comply with this requirement. The effect of their error is shown on Drawing 4 (Eng. Record, April 11). In view of the high unit stresses specified, this error was serious enough to have required the condemnation of the bridge even if it had not failed from errors in the design of the compression chords.

The obvious intention of the clause was to compel the designers to check their assumed dead loads by actual calculations from their detailed drawings as soon as these were developed, and it carried with it an obligation on the consulting engineer not to approve any drawings until he was satisfied that the assumed weights were ample. It is not customary in practice to be exacting about the observation of this clause, because the weight of an ordinary span for a given loading can be very closely estimated; but no excuse can be offered for applying the precedents of practice to a structure that was entirely outside the range of experience. No evidence has been given to show that any effort was made either in the Phœnix Bridge Company's office or by the Consulting Engineer to check the assumed weights at the earliest possible date and the error was passed without notice until a large portion of the bridge had been actually built in the shops and the members weighed. It is in evidence, and we have already stated, that the scale weights were within 1 per cent. of the weights as finally computed from the drawings. The consequences of this error were considered by Mr. Szlapka and Mr. Cooper before erection was resumed in 1906 and they state it was their opinion that the error was not fatal to the safety of the bridge, and the work of erection was proceeded with.

Erection.—No special provision is made in the specification for an oversight of the methods of erection by the Quebec Bridge & Railway Company's engineer, or for his approval of the general system of erection, or of the means adopted to solve the various problems arising in connection with it. There is no evidence to show that anyone outside the Phœnix Bridge Co. attempted to deal with this practical problem. Mr. Cooper states that the erection plans and devices were not subject to his approval, although he was advised of them unofficially and general progress on erection was regularly reported to him.

It was apparently intended, as is the usual practice, to leave all such arrangements in the hands of the contractor, making him provide all necessary plant and holding him responsible for everything that might happen.

The erection staff of a large construction company is best qualified by experience to design erection plant. We are of the opinion, however, that the erection difficulties to be met with on a structure like the Quebec Bridge are so serious and the necessary risks to be run during erection are so great that if the employment of a bridge engineer is necessary at all, it is especially necessary in this connection. In fact the responsible engineer on such a project should direct the work in all its branches and the contractor is entitled to look to him as a trained specialist for instructions and assistance at all times and especially in emergencies.

The specification throughout shows that the whole subject was not considered with sufficient care, not only from a technical standpoint, but from the practical or business standpoint as well. Inconsistencies are of frequent occurrence; ambiguity and lack of precise definition pervade the whole, and we desire to direct particular attention in this connection to the important clauses 4, 5, 6, which read as follows:

"(4) After the stress sheets have been approved and before the construction of any part of the structure shall be proceeded with, complete working drawings shall be furnished, showing all details of construction, which shall conform to the general design, shapes and dimensions shown on the stress sheets and to the conditions of this specification. The drawings shall be approved by the Engineer before the work of construction is proceeded with.

"(5) After the final detail drawings referred to have been approved by the Engineer, the Contractor is to prepare his shop drawings from the detail drawings, complying carefully therewith, and making no changes without the written consent of the Engineer. Working drawings are to be sent in triplicate for the approval of the Engineer, who will retain two sets and return the third after making thereon any corrections required, after which the required number of corrected sets will be sent by the Contractor to the Engineer without delay. The approval of the said working drawings will not relieve the Contractor from the responsibility of any errors thereon.

"(6) The requisite number of copies of general and detail drawings for all purposes shall be furnished by the Contractor upon orders of the Engineer."

(Signed) Henry Holgate, Chairman,
J. G. G. Kerry,
J. Galbraith.

Hand Drilling in granite, some of which was quite hard, cost 61 cents per lineal foot in quarries connected with the Salt River project of the U. S. Reclamation Service. The official report states that there were 28 holes drilled, having a total length of 397 ft. Labor cost $2.50 per 8-hr. day per man and the average number of feet drilled per day per man was 4.2.

Appendix 19, Report of Royal Commission on Quebec Bridge Failure.

The temperatures and wind velocities for some weeks preceding the accident are shown on Drawing 37 [not reproduced]. It will be noted that there were no exceptional conditions in either case, both temperature and wind being moderate and usual. The wind blowing at the time of the accident was so light that wind pressure has not been included in calculating the stresses existing at that time. The drawing shows a wind velocity late in the day on Aug. 29 of about 25 miles per hour, which would theoretically produce the almost negligible pressure of about 2 lb. per square foot on the truss surface exposed. The form of the truss is such that a correct analysis of the wind forces is most difficult to make and it was considered that less error would result from the neglecting of these forces than from an effort to determine them accurately.

A list of the maximum wind velocities recorded at the Quebec Observatory is given on Drawing 37 [not reproduced]. This list indicates that the pressure of 25 lb. per square foot assumed in the 1898 specifications was sufficient for the site, a wind velocity of nearly 90 miles per hour being necessary to produce such a pressure.

The accompanying record of deflections is of interest as furnishing data for predicting the movements of cantilever arms under wind.

Observations on the Deflection of the Cantilever Arm under Heavy Winds.

Nov. 12, 1906.—Front leg of large traveler at PI. Panel 2 of cantilever arm partly erected. East wind 55 miles an hour. Deflection taken on middle of first transverse strut above deck between posts PI. Deflection observed, 2½ in.

Nov. 16, 1906.—Front leg of large traveler at PI. Panel 2 of cantilever arm almost completed. East wind, 65 miles an hour. Deflection taken at same point. Deflection observed, 3½ in.

Feb. 3, 1907.—Front leg of large traveler at TO. Cantilever arm erected complete. West wind, 45 miles an hour. Deflection taken at same point. Deflection observed, 2 in.

(Signed) Henry Holgate,
(Chairman),
J. G. G. Kerry,
J. Galbraith.

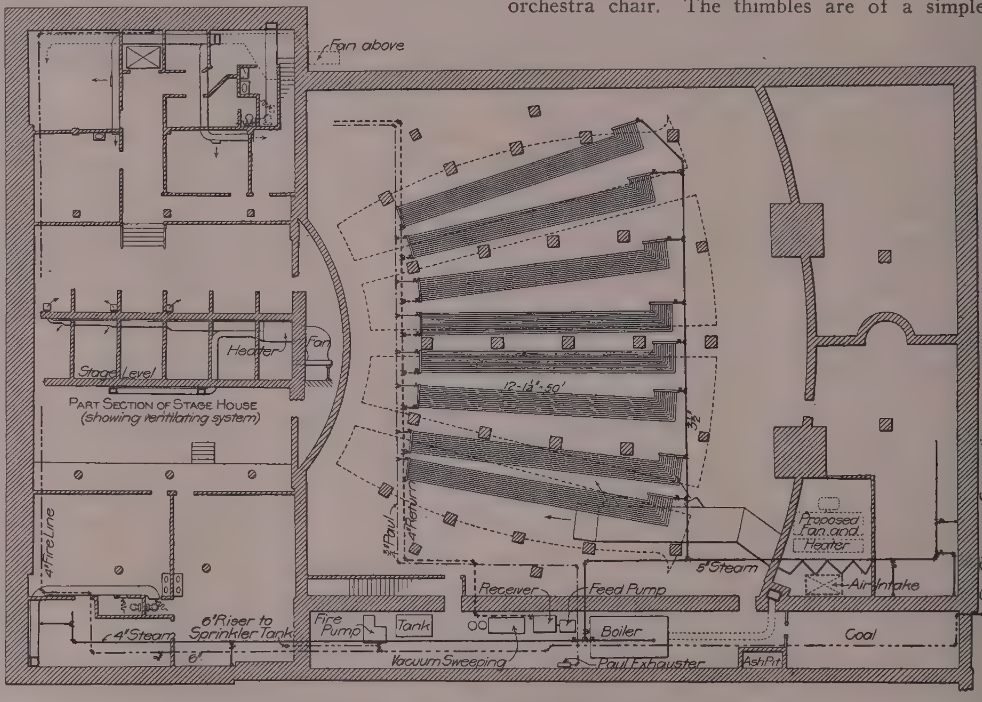
A Small Water Power Development.

The utilization of small water powers now going on in many parts of the country is typified by a development on Caney Fork River, a mountain stream in Tennesee, by the Bon Air Coal & Iron Co. The ordinary flow of the river will furnish 250 h.-p. under the head furnished by a concrete dam 26 ft. high. The power will be transmitted electrically a distance of two miles to the company's mines, where it will be used in operating pumps, coal washing machinery and for lighting purposes. The stream has a flashy character and an auxiliary steam plant will be necessary for use during low water. The dam will be about 316 ft. long and will have about 2,100 cu. yd. of concrete. The overflow section will be 108 ft. long, 4 ft. wide at the top, 16 ft. wide at the bottom and provided with a stepped downstream face. A public road now crosses the river by a ford just above the dam and, accordingly, the latter will carry a series of piers 20 ft. apart along its crest to support a bridge which will replace this ford. The dam will rest on solid rock, into which it is proposed to drill a number of holes for 2-in. anchor rods about 4 ft. long, which will project 2 ft. up into the concrete of the dam. The company has a large amount of discarded wire cables and old T-rails on hand, which it is proposed to utilize as reinforcement for the concrete. The work is under the charge of Mr. Sumter Lea, Jr., the company's chief engineer, and it is expected that the development will furnish current at a very low cost.

Heating and Ventilation of the New Forrest Theater, Philadelphia, Pa.

The Forrest Theater is a new playhouse recently completed at Philadelphia that is of elaborate modern design and involves many interesting features of construction and equipment. It is located on Sansom St., near the corner of Broad St., and it is so laid out that it has its main entrance on the latter main street, while there is the stage entrance and ample exits on Sansom St. at the side. It is a house seating an audience of about 2000, of which nearly 700 are accommodated on the main floor and over 600 each in the gallery and in the balcony. The theater building is of unusual design, being of reinforced concrete construction throughout and having in its main and side entrances a novel arrangement of corridor inclines, permitting entrance direct to either main floor or balcony without the use of stairs.

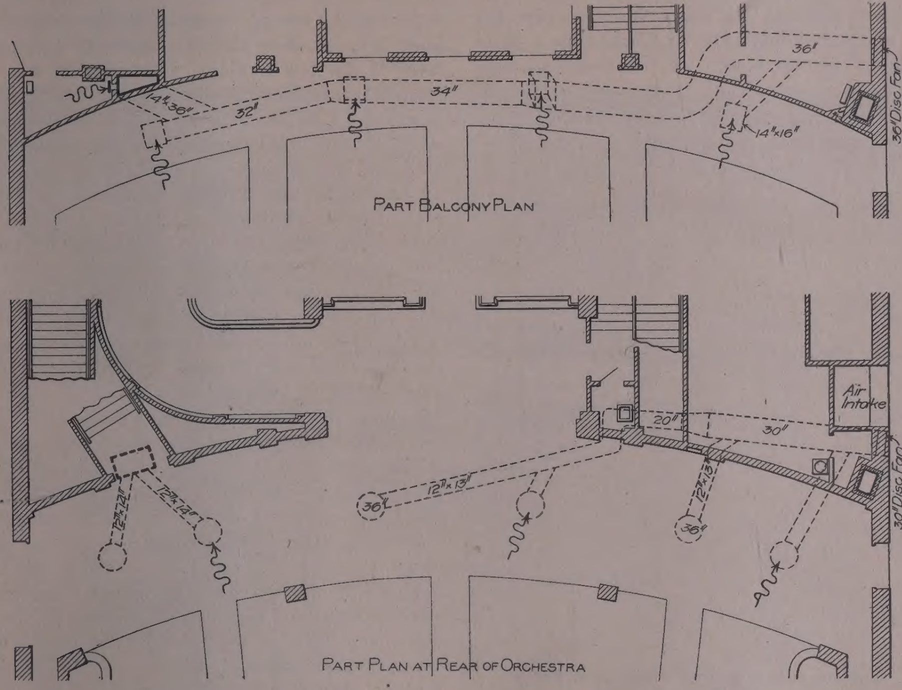
Careful attention was given in the design of the structure to the questions of heating and ventilation as well as also to fire protection. It was the desire that all public portions should be fitted for mechanical ventilation, and as the unusual specification was made that the heating equipment should be capable of maintaining the temperature within the building to 72 deg. Fahr. with a steam pressure not to exceed 10 lb., when the outside temperature is as low as 5 deg. below zero, features of unusual interest enter into the design of the equipment. The theater building is heated by steam on the low-pressure system which is applied in the auditorium by indirect radiation and direct radiation in other portions of the building. The ventilation is accomplished by an upward flow, the fresh air being admitted to the auditorium at the floor level while the exhaust ventilation is through openings in different portions of the ceiling, and an unusual feature of the installation is the use of a form of induced draft for the fresh air supply to the auditorium instead of a system of fan blast delivery, the exhaust ventilation which is mechanically operated by fans, serving, by the withdrawal of air from within this space, to induce the fresh air supply from an outside intake through a suitable heating chamber. The system has been so designed in regard to the fresh air intake, heating chamber and admission openings to the auditorium that the effect of the exhaust fans when operated to full capacity, is to change the air within the auditorium space approximately four times per hour.



Heating Equipment in the Basement of the Forrest Theater, Philadelphia.

The auditorium, which is 82 x 88 ft. in plan and 56 ft. in interior height, and has both a balcony and gallery and boxes on the three levels, was laid out with special reference to facilitating the ventilation. Underneath the main floor there is a shallow basement space which is enclosed and finished with a cement floor and serves as a plenum or hot air distributing chamber for the auditorium supply, while the furred ceiling spaces underneath the two galleries and over the main auditorium provide for the exhaust gathering ducts for the removal of foul air. The plenum chamber is of the full size of the auditorium, and due to the sloping main floor of the latter, has a headroom of about 5 ft. at the proscenium wall which increases to about 10 ft. at the rear. The air openings for the admission of air from this chamber to the auditorium consists of 5-in. thimbles with diffusing hoods which are set into the concrete floor construction under every other orchestra chair. The thimbles are of a simple stove pipe construction of No. 18 black iron with plain flat caps mounted above the openings in order to spread the flow of air under the seat and prevent draft being felt by the occupants of the chairs. This arrangement of inlets provides a very general distribution of the air supply over the auditorium and owing to the large number of openings, approximately three hundred 5-in. thimbles, a comparatively low delivery velocity is secured with the ventilation system operating to its full capacity. The 300 inlet thimbles provide a total opening of approximately 41 sq. ft. which for a ventilating duty of four changes of air per hour throughout the auditorium space, equivalent to the delivery of 26,500 cu. ft. of air per minute, results in an average delivery velocity from the thimbles of about 650 ft. per minute.

The plenum chamber is, as above stated, not fitted with a fan system of fresh air supply, the air being drawn through the latter and delivered to the auditorium by the combined induced draft effect of the exhaust fans that withdraw air from the upper portion of the auditorium and of the large area of pipe heating coils distributed throughout the chamber underneath the thimble openings. These heating surfaces consist of horizontal mitre coils containing approximately 5,000 lineal ft. of 1¼-in. pipe, which are suspended from the ceiling of the chamber and as near to the thimble openings as the inclined surface of the ceiling would permit, the distribution of the coils being such that there is heating surface directly under all of the thimble openings. For this purpose the surface was divided into eight of the horizontal coils which are of 1¼-in. pipe, built up of 12 pipes in 50-ft. lengths and each unit contains approximately 260 sq. ft. of radiation, giving a total of 2,080 sq. ft. of radiation for the entire chamber. With the total delivery of 26,500 cu. ft. of air per minute, necessary for the four changes per hour in the auditorium, which in order to fulfill the terms of the guarantee must be raised from the extreme temperature of —5 deg. to 72 deg. Fahr., a total of 37,100 B. t. u. must obviously be communicated to the air supplied per minute; this transmission, with the total heating surface of 2,080 sq. ft. is at the rate of 1,070 B. t. u. per hour per square foot of radiation, which with between 700 and 800 cu. ft. of air passing over each square foot of radiating surface per hour, is a satisfactory figure for pipe coil radiation, when arranged in this manner and surrounded by comparatively still air.



Arrangement of Exhaust Connections at the Rear of the Auditorium.

The fresh air which is drawn into the chamber passes in through a 48 x 75-in. duct that is carried up to a screened intake window at about the first floor level, in the open interior court at the left side of the auditorium which serves both as the fire exit passage and the stage entrance. This duct which is merely a furred enclosure at the first floor level, is carried down into a 15 x 20-ft. enclosure in the basement that serves as a filter chamber and also to accommodate a proposed blower, if it shall be decided at any furture time to substitute forced blast in place of the present arrangement of induced fresh air supply. From this chamber, a 45 x 78-in. galvanized iron rectangular duct is carried forward in the plenum chamber at a height of about 3 ft. above the floor to a 38 x 75-in. outlet near the middle of the chamber. It has also two 20 x 48-in. side outlets so directed as to deliver the air toward the center of the chamber, and all of the outlets direct the air delivery toward the floor so as to prevent the air from passing above the heating coils and entering the auditorium without being heated. With this precaution it is found that the air entering the chamber, being direct from the outside and cold, descends directly to and follows the floor line from which it diffuses evenly up through the pipe coils and is uniformly heated. The air filter is of the zig-zag cheesecloth type, the filtering medium being distributed over eight frames, which present a total area of about 12 times the area of the intake and reduces the velocity of the air through the filter to a point where satisfactory cleansing is ensured.

The exhaust ventilation of the auditorium is accomplished by three disc exhaust fans, each with duct connections to vent registers at different ceiling levels, as, owing to the extreme slope of the balcony and gallery floors, it was found desirable to exhaust from the ceiling spaces of each level. For simplicity the three systems are operated entirely separately, the ceiling space under the balcony being exhausted by a 30-in. exhaust fan, that under the gallery by a 36-in. fan, and the main ceiling space of the auditorium being exhausted at the rear by a 42-in. disc fan. These fans are all located in wall openings into the open court on the stage entrance side of the building and in order to permit of a minimum of duct work, are so located as to have nearly horizontal connections through furred ceiling construction to the vent registers served in each case. The ceiling underneath the balcony is fitted with six vent registers which are fancy grilles 33 in. in diameter, although but four of these are connected to the 30-in. fan which is located at this level, the two on the side farthest from the fan being connected owing to obstructions within the ceiling, through a riser duct in a furred enclosure to the duct system operated by the fan on the level above, which is a 36-in. fan. These circular registers have 12 x 13-in. branch connections to the fan duct, which latter is from the main fan connection a 30-in. round galvanized iron pipe of No. 24 galvanized iron for half of its length, reducing at that point to a 20-in. round duct for connection with the two farther registers. The two registers on the far side connect through an irregular shaped enclosure about 18 x 54 in. in section to the balcony ceiling space where a 14 x 36-in. rectangular cross duct connects the same with the balcony system that is operated by the 36-in. fan. This system has four 14 x 16-in. register openings distributed over the highest portion of the balcony ceiling which have short direct connections to a circular exhaust duct that leads to the fan. This duct is 36 in. in diameter at the fan connection, diminishing to 34 and to 32 in. in diameter at the farther end. The gallery system has for its duty the ventilation of not only the space above the gallery, but also in general from the auditorium at large, and is consequently of large capacity, being operated by a 42-in. disc fan. A 42-in. circular galvanized iron duct is carried from the latter to connect with six 24 x 36-in. register openings in the main auditorium ceiling at the extreme rear. These registers have 22-in. connections from the main duct, which reduces to 38 and 32 in. in diameter as the latter connections are taken off.

Between these fans is divided the duty of ventilating the entire auditorium, which for the required four changes of air per hour necessitates the removal of approximately 26,500 cu. ft. per minute. These fans are all of the multivane disc type with special spider mountings for direct electric motor drives, which are built by the American Blower Co., Detroit, Mich. They are equipped with 1, 1½ and 2-h.p. Diehl direct-current motors which are designed for speeds of 625, 525 and 460 r.p.m., at which maximum speed the fans have capacities of 6,000, 8,500 and 12,000 cu. ft. per minute respectively. The fans have plain circular angle-iron frames which are set directly into the brickwork of the outer wall to discharge into the open court above the stage entrance, and their motor driving outfits are in each case enclosed in substantial box enclosures of No. 12 iron which in each case are connected between the fan frame and the exhaust ducts and facilitate access to the motor for attendance.

Auxiliary ventilation is also provided for in the building for such of the dressing rooms at one side of the stage as have no outside window openings and for toilet rooms, two of which are in the basement of the stage division and two are public toilets provided in connection with the gentleman's smoking and ladies' retiring rooms. The first service consists of a fan operated system of fresh air supply to 9 dressing rooms located on the right-hand or westerly side of the stage. The fan is a 50-in. full housed steel plate blower with 30-in. wheel, which was also supplied by the American Blower Co., and is located upon an enclosed steel platform over the stage entrance in an open court space on the westerly side of the auditorium. It has a direct intake from the court space and delivers direct to a heating coil immediately within the stage wall, from which two rectangular ducts extend to connect with the dressing room registers; one, a 10 x 24-in. duct, is carried on the ceiling over the stage floor and supplies air to two dressing rooms on that level and three rooms on the second tier immediately above, while the other duct, 10 x 18 in. in section, drops into the basement underneath this space and supplies four auxiliary rooms. The blower is direct driven by a 3-h.p. Diehl direct current motor, operating at 340 r.p.m., at which speed it has a delivery capacity of 6,000 cu. ft. per minute. The heater of this system is enclosed in an enlargement of the delivery duct to 5½ x 8 ft. in plan by 3 ft. deep and contains a pipe coil of sufficient surface to warm the air to a temperature of 70 deg. Fahr. at full capacity of the fan when the outside temperature is —5 deg.

The toilet exhaust systems consist of exhaust duct connections to the ladies' and gentlemen's toilet rooms adjoining the retiring and smoking rooms under the foyer which systems are operated by 12 and 24-in. Blackman disc exhaust fans respectively, which are calculated to withdraw 1,500 and 5,000 cu. ft. per minute from these spaces. Two groups of toilet rooms in the basement space underneath the stage are ventilated by natural draft, 12 x 24-in. exhaust flues being carried from them up through furred enclosures to hooded openings above the roof of the stage division. Each of these vent ducts has a 12 x 24-in. register face opening into each of two toilet rooms.

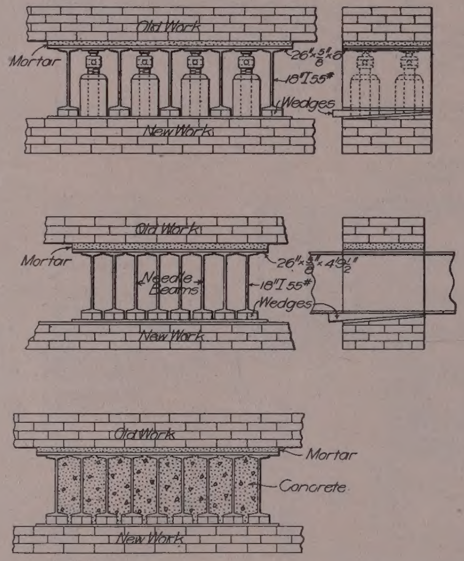
The heating of the stage, the dressing rooms, the entrances and the auxiliary rooms of the theater is accomplished by direct radiation throughout which is operated at low pressure on the one pipe system with auxiliary piping for air returns. A total of about 2,000 sq. ft. of radiation has been installed for this purpose, exclusive of the heating surface installed in connection with the two fresh air supply systems. Of this amount 421 sq. ft. has been installed in large pipe coils on the side and rear walls of the stage and about 700 sq. ft. in the dressing and auxiliary rooms off of the stage on either side. At the entrance end of the building, some 855 sq. ft. were installed in the corridors, retiring rooms and auxiliary rooms on the Sansom St. front, and 500 sq. ft. in the main entrance foyer which extends through to Broad St., and subsequently two units aggregating 150 sq. ft. have been installed in the former entrance to provide for an indraft found there. The distribution of this radiation has been proportioned on the thermal unit basis of heat loss for the greater part, the locations selected being generally under window sills with connections to the risers exposed above the floor level. The pipe coils at the rear of the stage are owing to the large interior heated, of very large size, that on the side wall being a 10-row coil of 1¼-in. pipe, in 20-ft. lengths and that on the rear wall a 60-row coil in 78-ft. lengths. In all other parts of the house cast-iron radiation is used which is installed in the National two, three and four-column types for the standard radiation, the Detroit flue type for low radiators and the Peerless type for the dressing rooms.

Steam is supplied to this radiation by 20 riser pipes, 11 of which serve the radiation in the entrance end while the remainder supplies the radiation on the stage and in the dressing rooms. The risers range in size from 1¼ to 3-in. pipes, according to the radiating surface supplied, and are for the greater part carried up through five floor levels, four being installed to supply only main floor radiator units, and three to second and third floor levels. The risers are in general run exposed with asbestos pipe covering, canvas jacketed, and each is paralleled by a ½-in. air return riser from which vapor connections are made to the radiator units. The latter air risers are connected in the basement of the building to a ¾-in. gathering main that leads to a Paul system exhauster in the boiler room. The steam supply risers have connections to a heat distributing main in the basement through valved branches and this main which is carried as a 5-in. line to the front of the building and a 4-in. line to the rear is so graded as to drain the condensation returns from the risers with the flow of steam. At the extreme end of each branch a large size condensation return line is connected to return water of condensation to the boiler. The circulation of steam has from the first been found to be free and noiseless with a boiler pressure of less than 1 lb.

The boiler is a fire-tube externally fired boiler of the Economic type built by the Erie City Iron Works and has a rating of 90 h.p. The boiler shell which is of locomotive boiler form is 13½ ft. in length by 9½ ft. high and is 60 in. in diameter in the barrel portion. It has a heating surface composed of eighty-eight 3-in. tubes in the barrel portion which are 9½ ft. long and forty-six 4-in. tubes in the fire box section which are 54 in. long. The grate which is located underneath the barrel in front of the fire box section is 60 x 72 in. in area. While designed for a higher pressure, the boiler is operated normally at a pressure from 3 to 5 lb. The furnace is fired with anthracite coal which is stored in the 10 x 30-ft. pocket formed in the space underneath the driveway to the stage entrance in front of the boiler room; this pocket has a capacity of over 100 tons of coal which is dumped into it through sidewalk coal holes in the roof of the passageway.

The boiler is fed by condensation returned from the heating system, a portion of which returns by gravity while the remainder is returned by pump. The return connections from the front or entrance portion of the building are on such a level as to permit of return by gravity whereas the return connections under the stage are at a much lower level and are therefore connected to discharge into a depressed receiver tank from which the condensation is pumped to the boiler. The feed pump is a Goulds triplex pump direct driven by a 1 h.p. motor. This pump as well as also the boiler has connections to the city water service to permit of feeding cold water direct if necessary. The feed pump motor is governed by a float switch connected to a float in the receiving tank which causes the water to be returned to the boiler as rapidly as it accumulates.

A feature of the auxiliary equipment of the theater is the vacuum cleaning installation, a two-sweeper electrically driven plant having been installed with a series of basement gathering mains and risers through the upper floors so that any part of the building may be reached by a 50-ft. length of suction hose. The vacuum apparatus consists of a combination of wet and dry separating tanks with vertical reciprocating pump supplied on the Lotz patents by Sanitary Devices Mfg. Co., San Francisco, Cal. The pump is driven by an 8-h.p. Westinghouse motor and has a capacity of maintaining a 15-in. vacuum when the two sweepers are in operation simultaneously. All the fittings used in the sweeper piping are of the long-sweep drainage pattern in order to avoid obstructions due to material lodging at bends or on rough projections, and the wet tank has a drainage connection to the sewage ejector beneath the stage.



Jack Screws and I-Beams under the Ferguson Building.

The heating and ventilating equipment of the theater was designed and installed by the Malcolm W. Hill Co., engineers, Philadelphia, Pa. The architects of the building are Marshall & Fox, Chicago, Ill. The general contractors for the building were Cramp & Co., Philadelphia, and the Brady-Dackert Co., Philadelphia, Pa., were contractors for the interior finish.

Ten Heavy Freight Locomotives have recently been completed by the American Locomotive Works for the Boston & Albany R. R. They are of the 4-6-0 type and weigh 208,000 lb., exclusive of the tender. The total engine base is 26 ft. 10½ in. The cylinders are 22 in. in diameter and 26 in. in stroke and will be furnished with steam at 200 lb. The valve gear is of the Walschaerts type. The use of these engines will impose considerably heavier loads on the Boston & Albany track and structures than ever before.

Underpinning the Ferguson Building.

The Ferguson Building is adjacent to the new Commonwealth Trust Building, Pittsburg, and when the foundations of the latter were carried down through clay and gravel to a much greater depth than its own foundation, it became necessary to underpin the 10-story rear brick walls and to provide new supports for a battery of boilers close to the wall in the basement. Between the two rows of boilers and about 10 ft. clear of the wall, a pit 4 ft. square was sheeted down below the footings of the new exterior foundations and in it was built a solid brick pier supporting double cantilever I-beams, thus carrying the boilers on both sides.

A recess was cut in the brick-work at the corner of the building near the second floor and in it was seated the upper end of a nearly vertical 12 x 16-in. timber 48 ft. long. The lower end of this shore was seated on a 16 x 16-in. sill supported by ten 25-ton jacks on timber cribbing built in a pit sheeted down about 15 ft., to the level of the new footing. This cribbing was extended across the full width of the building and a group of jackscrews set on it to carry six 24-in. I-beam needles which passed through the wall and were supported at their opposite ends by jackscrews and cribbing on top of the boiler pier already mentioned.

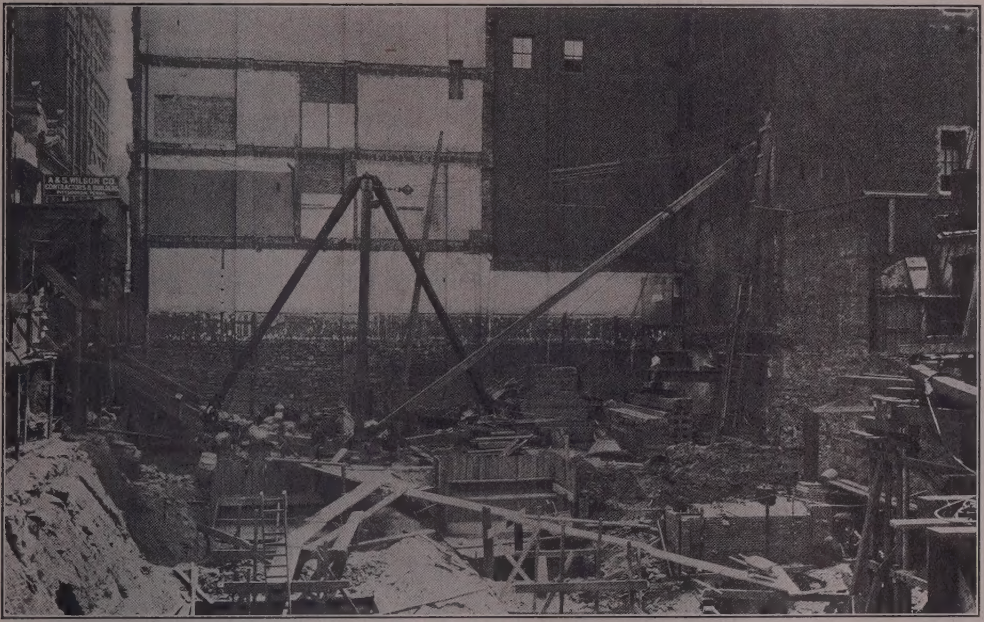
The old footings of the wall were supported and 4 x 6-ft. excavations were carried down under them to the required level and sheeted with horizontal 2-in. planks. Each one was filled to within 18 in. of the old footing with concrete, on the upper surface of which was bedded a ⅝-in. steel plate 6 ft. long and as wide as the thickness of the wall. The inner edge of the plate was set about 1½ in. higher than the outer edge, inclining the surface to correspond with the bevel of 3 x 2½-in. cast-iron wedges afterwards used. Short drums were set on this plate and a corresponding plate was placed on top of them 4 in. clear of the wall above and was covered with 1:1 cement mortar. The jackscrews were set up until the mortar was forced against the brickwork and left so until hard. Short I-beams, transverse to the wall, seated on two cast-iron wedges, side by side, were placed on both sides of the drums and in the spaces between them. When the mortar was hard enough to be loaded the screws were set up, and the wedges, previously greased, were driven to correspond with heavy sledges. In this way the load was transferred from the needle beams to the new footings and the latter were settled to their final bearings.

When a pair of wedges was nearly driven before the footings were settled to their final position one of the wedges was driven a little in advance, releasing the other so that it could be removed and ¼ or ⅜-in. steel shim placed under it, when it was replaced and the other web removed and shimmed in the same manner.

The underpinning was commenced in the middle of the wall and the piers were built in succession to both ends. When all was completed the building was supported on jackscrews, beams and wedges and the former were very easily removed and the wedges were very useful in assisting the screws which were found to be very much relieved by their use. As the loads concentrated on the different underpinning piers were considerably greater during their construction than their respective ultimate portions of the weight of the building, their footings were thoroughly compressed so that there was no danger of subsequent settlement. The bulk of the adjustment was always made with the jackscrews, followed up by the wedges which were quickly tightened with a few blows of the sledge. After the jackscrews were removed, the forms were built on both sides of the wall and the spaces around the I-beams were filled with concrete and grouted. This method of underpinning was considered very economical and satisfactory, especially in that it dispensed with mason's work and permitted the footings to be settled by the jackscrews, avoiding the wedging and shimming with slate and other materials that it so frequently resorted to and is both expensive and is likely to be unsatisfactory, unless subject to very careful superintendence. The work was designed and executed by the John Eichleay Jr. Co., Pittsburg.

Book Notes.

A good example of the class of books best suited for journeymen is Mr. A. G. King's "Practical Steam and Hot Water Heating and Ventilation." The two common faults of such books, verbosity and inaccuracy, are not present and the author explains his subject in a clear way that can be understood by the steam-fitter and does not offend the technically educated engineer, although the latter might like to see changes made in the wording of parts of the first and second chapters. The book describes all features of steam and hot-water heating installations, ventilating plants, warming systems for swimming pools, the business methods of conducting steamfitting work and the care of heating plants, and gives a large collection of rules, memoranda and tables. The contents are unusually comprehensive, and while the book is in no sense an engineering work, it is a good explanation of the scope as well as details of the work done by a contractor for heating and ventilating plants. The illustrations are numerous, well selected and well engraved. (New York, Norman W. Henley Publishing Co., $3.00.)



Corner Wall of Ferguson Building Supported by Shores and Crib-Supported Needles.

A little book that has been of value to many fire insurance agents and tax appraisers, "Brown's Estimates and Agents' Companion," has been recently revised in order to agree with the great advance in the cost of building materials and labor in the last three years. The primary object of the book is to afford safe rules for estimating the value of a building by the cubic foot method, in order to determine the amount of fire insurance that it is safe to place on the structure. This method is necessarily only approximate, and its use requires considerable experience and knowledge of building methods in order to yield close results, but it is better adapted for estimating the value of an existing structure than one for which only plans and specifications are in existence, so that some of the objections to it for the latter work do not hold when it is employed for insurance and tax purposes. This little book contains the most complete directions for the use of the method in estimating the value of all kinds of buildings that have been published, and also gives a large amount of information concerning special hazards and other insurance matters which business men as well as insurance agents will find useful for reference. (Indianapolis, Rough Notes Co., $1.00.)

The second volume of the "Handbuch fuer Eisenbetonbau," which is being published under the general editorial direction of Dr. F. von Emperger is devoted to the materials and methods employed in the execution of reinforced concrete structures. The section on materials was written by Messrs. K. Memmler and H. Burchartz and is a detailed description of the properties of steel, Portland cement, sand, gravel, stone and cinders, motar and concrete, and the methods of testing mortar and concrete. The second section, on the equipment and methods employed in concrete work, opens with a chapter on concrete mixers, written by Mr. H. Albrecht. This is followed by several chapters written by Mr. R. Janesch, on the choice of materials, mixing and adding water, means and methods of handling materials, placing the concrete and protecting it against weather conditions, and handling and placing the reinforcement. The two closing chapters, written by Mr. Otto Rappold, describe a great variety of forms and the methods of handling them. This information is arranged in two parts, relating to buildings and bridges respectively. The purpose of the author has been to explain by well-chosen examples the great variety of types of centering and molds that have been used in different countries, a task he has accomplished with marked success. (Berlin, Wilhelm Ernst & Sohn, 12 marks).

A new edition of Mr. Louis de Coppet Bergh's "Safe Building Construction," which has just appeared, shows that this standard treatise on the structural features of architecture is still appreciated by draftsmen although parts of it appeared more than twenty years ago. The author's aim has been to give simple rules for computing the strength of all parts of a building and to explain those methods of design which will give satisfactory results. The book takes up the strength of building materials, foundations, cellar and retaining walls, arches, floorbeams and girders, reinforced concrete (this part being very sketchy), riveting, plate and box girders, trusses and columns. The treatment of these subjects is such as is best adapted for use in an architectural drafting room and no attempt is made to follow the elaborate mathematical methods of engineering textbooks. There are a great many useful tables and diagrams, but it is a pity that so many of them relate to wrought iron, a material no longer employed in building. They cannot be employed for steel except by a multiplication of the tabular numbers by a coefficient. (New York, The Macmillan Company, $5).

The report of the U. S. Coast and Geodetic Survey for 1907 contains a number of articles of much interest. One of these relates to the determination of the effect of the California earthquake of April, 1906, on the lengths and directions of lines joining triangulation stations. A new triangulation was made from Point Arena to stations south of Monterey Bay, by which the new location of 61 old stations was determined. This work extended 22 miles west of the great fault accompanying the earthquake and 33 miles east of it, and traces the displacement of the earth's crust for many miles back of the fault in each direction, showing that it follows certain regular laws. This is probably the most extensive and accurate determination by triangulation of earthquake effects that has ever been made. Another feature of the report is an account of the measurement of six primary bases with steel and invar tapes. This work showed that measurements can be made more conveniently, accurately and at smaller cost per mile with invar tapes than with steel tapes, and that the former are sufficiently durable and stable for safe field use. Another section particularly interesting to surveyors as well as to navigators refers to the progress in the magnetic survey of the country and also in equatorial regions. Numerous "repeat" observations have been made in order to follow as closely as possible the secular change in the magnetic elements. Still another section of the report is the concluding portion of the "Manual of Tides," which has been in preparation for a number of years. It takes up the flow of water, river tides, tidal currents, permanent currents, annual inequality, lake tides, seiches and miscellaneous tidal matters. The analysis of observations upon the tides of Lake Superior show that they follow closely the equilibrium theory, although the tidal range is only 1½ in. at Duluth and 1/3 in. at Marquette. A good many engineers engaged in hydraulic works will find the section of the volume on the long-wire drag of considerable value. The drag is a device for detecting erratic obstructions of small extent in navigable waters. The method of operation can be understood from the simple statement that the drag is a wire varying in length from 480 to 1,400 ft., supported at suitable intervals and maintained at any desired depth below the surface of the water. This drag is towed over any given area by launches, and in the area so searched no elevation of the bottom above the depth at which the wire is suspended can escape detection. Buoys floating at regular intervals above the drag indicate to observers in the launches when and where an obstruction is touched and the spot so indicated is then accurately determined. This method of sweeping has proved a sure means of detecting pinnacle rocks and similar obstructions which heretofore have eluded the hydrographic surveyor, since it is almost impossible to detect them by sounding with a lead. Only the navigator in whose hands rest many lives and much property can realize the relief from mental strain that comes from knowing that the water in which he is sailing is absolutely free from hidden dangers or that every menace is charted.

Letters to the Editor.

The Fire in the Newport Pumping Station.

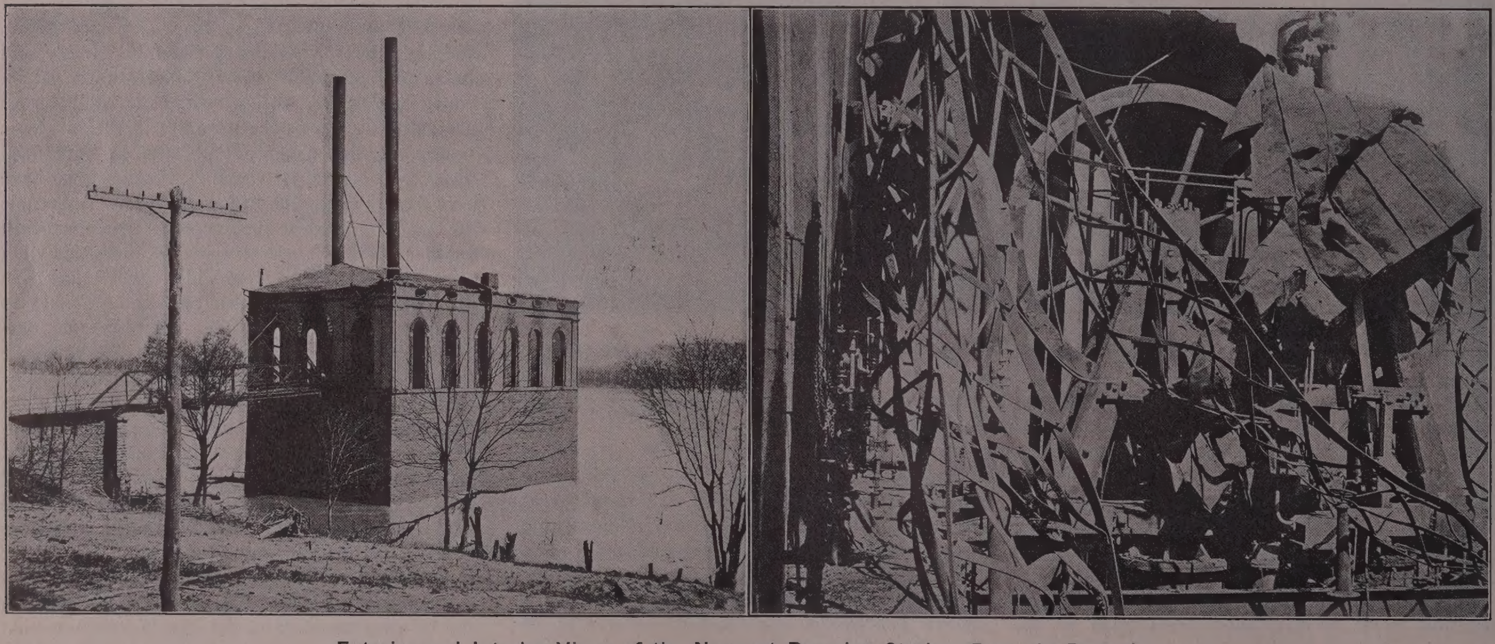
Sir: The pumping plant of the Newport, Ky., water-works was greatly damaged by fire on the night of April 5. The pictures give an exterior view of the building and the interior of the engine room. The plant was shut down the evening before to observe Sunday and hence there was no fire in the building.

It will be noted that the building sets out in the Ohio River, and the boiler room end of it is connected with the shore by a bridge. Some 25 years ago the Government established a gauge on the wall of the river end of the structure, indicating for passing steamers the head-room under the Ohio River bridges at Cincinnati. For day use the figures on the wall gave the stage of the river and for night an illuminated self-adjusting gauge encased in one of the windows gave the desired information. A kerosene lamp was used at night to illuminate and make visible the figures on the gauge. The lamp was lit in the evening as usual by one of the employees, who left the building after locking up. It is believed that the lamp became disordered and was the cause of the fire.

Newport and Covington are adjoining towns, separated by the Licking River, but connected with one another by bridges, one of which carries an emergency main to be used to supply either city from the other in case of an accident to either plant. This connection will prove very fortunate for Newport at this time, as Covington is amply provided with reservoir capacity and pumping machinery to easily supply both cities. Newport will not be able to restore its pumping plant for at least six months.

Yours very truly,
George Hornung & Son.

Cincinnati, April 14.


Exterior and Interior Views of the Newport Pumping Station Recently Burned.

Retaining Wall Design.

Sir: In The Engineering Record of Dec. 21, 1907, were given several views of reinforced retaining walls erected by the Delaware, Lackawanna & Western Railroad Co. in the city of Buffalo. In the article describing them the statement was made that for walls not over 12 ft. high they were made of L-shaped section while those over 12 ft. high were made with counterforts, with the remark that the L-section was not found so economical for walls over 12 ft. high. The writer has found the L-section and the inverted T-section more economical than counterfort walls for all heights he has been called on to design, some as high as 36 ft.

He recently designed a reinforced wall in which the requirements were that it should equal the standard gravity wall used on the Pennsylvania Avenue subway in Philadelphia, Pa. (See Trans. Am. Soc. C. E., Vol. 48, p. 470.) These designs make such a good showing for the L and T sections that they are sent you for publication if you desire.

Fig. 1 shows a section of the gravity wall referred to, while Figs. 2 and 3 are reinforced walls of the same height, 28 ft. 4 in. The wall shown in Fig. 2 is more stable as to overturning than the gravity wall, as with the maximum load acting the resultant strikes nearer the center of the base. The extreme downward pressure at the toe is less and therefore the foundation is less liable to settlement at that point. The resistance to sliding on the base is slightly more, as the combined weight of the wall and the earth on the heel is a little more in Fig. 2 than in the gravity wall. For internal stresses the reinforced walls are figured with a factor of four for the loads assumed.

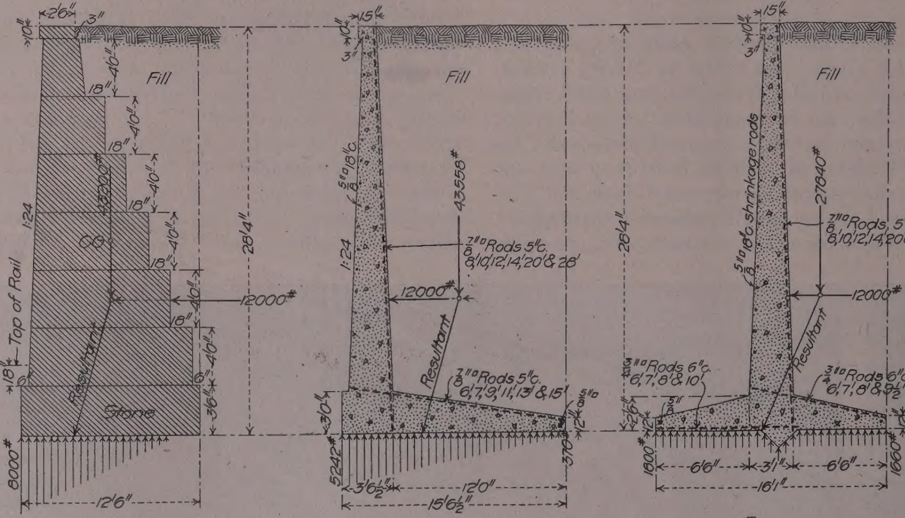

2'6"
3"
10"
4'0"
18"
Fill
1:24
43300#
Top of Rail
18"
6"
3'6"
Resultant
Stone
12000#
28'4"
8000#
12'6"
15"
5/8" ⌀ 18" c.
43558#
7/8" ⌀ Rods 5" c. 8', 10', 12', 14', 20' & 28'
12000#
Resultant
7/8" ⌀ Rods 5" c. 6', 7', 9', 11', 13' & 15'
3'0"
5242#
370#
3'6½"
12'0"
15'6½"
5/8" ⌀ 18" c. shrinkage rods
27840#
3/4" ⌀ Rods 6" c. 6', 7', 8' & 10'
3/4" ⌀ Rods 6" c. 6', 7', 8' & 9½'
1800#
1660#
6'6"
3'1"
16'1"
Fig. 1 Fig. 2 Fig. 3
Three Types of Retaining Walls.

Fig. 3 is for a location where the foundation is liable to compression, or where it is desired to avoid excavation at the rear of the wall. In this design the wall has absolutely no tendency to overturn with any load not greater than that assumed, and has no tendency to unequal settlement as the pressure is equally distributed over the foundation. The resistance of this wall to sliding forward on the base is less than Figs. 1 or 2 as the weight is less. The tendency to slide is not excessive, as the angle of friction is but 23 deg. However, to make the resistance equal to that of the gravity wall, a key is extended into the foundation.

The construction of this type of walls is much simpler than for counterfort walls. The forms cost less than for a concrete wall of the same section as the gravity wall shown at Fig. 1. The reinforcing is all simple, with no bent rods.

A comparison of the costs was made on the following basis of unit prices: Gravity wall, $6 per cubic yard; reinforced walls, $6.50 per cubic yard; steel in place, 3 cents per lb. The results show that Fig. 2 would cost 47.5 per cent. less than Fig. 1 and that Fig. 3 would cost 47.9 per cent less than Fig. 1. In case of excavation being required into a bank at the rear of the wall, the excavation for Fig. 2 would be more than for Fig. 1, while for Fig. 3 it would be less. This is certainly a good showing for the reinforced wall designs, which are in no point inferior to the gravity wall; and in the pressure on the foundation at the toe, where Baker says over 90 per cent. of retaining wall failures occur, they are vastly superior, as under the load assumed the extreme pressure at the toe of the gravity wall is 52 per cent. more than for Fig. 2 and 344 per cent. more than for Fig. 3. Yours truly,

Cincinnati, March 27. Frank A. Bone.